1

The Pennsylvania State University

The Graduate School

Department of Industrial Engineering

THE EFFECT OF SPECIFIC COMPONENTS IN THE TASK OF ARMORED VEHICLE RECOGNITION

A Thesis in

Industrial Engineering

by

Ralph W. Briggs

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

August 1992

I grant The Pennsylvania State University the nonexclusive right to use this work for the University's own purposes and to make single copies of the work available to the public on a not-for-profit basis if copies are not otherwise available.

Ralph W. Briggs

We approve the thesis of Ralph W. Briggs.

Date of Signature

Joseph H. Goldberg 5/4/92
Associate Professor of
Industrial Engineering
Thesis Advisor

Andris Freivalds 5/4/92
Associate Professor of
Industrial Engineering

Allen L. Soyster 5/4/92
Professor of Industrial Engineering
Head of the Department of
Industrial and Management Systems
Engineering

ABSTRACT

During Operation Desert Storm, numerous incidents of forces of the same side firing on each other occurred. These incidents of "friendly fire" accounted for 80% of the American armored vehicle losses and 107 American casualties. Determining the cause of these incorrect recognitions is important to prevent further needless losses.

Ten Army officers attending The Pennsylvania State University participated in a study to determine the perceptual and cognitive processes that occurred when recognizing armored vehicles. The subjects responded to vehicles as friend or foe when presented with 35mm slides at presentation times of 500 ms and 100 ms. The proportion correct, mean RT, d', and a values were calculated.

The results revealed that dual process processing occurred for the different type vehicles. Foe vehicles were better recognized when presented as a single component, the turret. Friend vehicles were better recognized as whole forms. The implications of these results are that separate training and search strategies should be employed depending on the type of vehicles which are being searched for. In the civilian sector, there are implications for how visual search and inspection are done in industry.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to express my thanks to my advisor, Dr. Joseph H. Goldberg, for his guidance and understanding during the preperation of this thesis and to Dr. Andris Freivalds for his constant support. I would also like to thank my fellow students in the Penn State Human Factors Laboratory for their support and help throughout the last two years. I would especially like to thank R. Darin Ellis for his constant help and counsel.

Above all I would like to thank my wife, LuAnn, and daughter, Bethany, for their patience, support, and love during the past two years. Without their help and understanding none of this would have been possible.

Chapter 1

INTRODUCTION AND BACKGROUND

The purpose of this study is to examine the problem of vehicle recognition on the battlefield. This study will examine the scope of the problem, provide some background on the factors affecting recognition, and examine some of the areas requiring study to solve the problem.

1.1 Problem Statement

The task of recognizing an armored vehicle under the extreme conditions of combat has been of concern since the first tank versus tank battle occurred in World War I. The ability of the crewmen in a tank or other armored vehicle to correctly identify a vehicle as friend or foe impacts on tactical success. The recognition problem extends to others besides armor crewmen. Infantrymen, equipped with lethal anti-armor systems, must also be able to perform vehicle recognition on the battlefield. The addition of Close Air Support by aircraft on the battlefield adds another highly lethal element to a situation which is usually chaotic at best.

Recent events in the Gulf Conflict with Iraq clearly show that, even under the most favorable of circumstances, the possibility of fratricide within friendly forces is immense. Fratricide, or friendly fire, is the situation in which forces are engaged by other forces of the same side. The U.S. and its allies incurred numerous casualties during both the air war and ground phases of the campaign due to fratricide. During Operation Desert Shield and Desert Storm, nearly a quarter of American casualties were the result of friendly fire (Harmeyer and Antal, 1992). Thirty-five of the 148 Americans killed were killed as the result of friendly fire. In addition to the deaths, 72 out of 467 Americans were wounded by friendly forces. Officials said American forces accidentally destroyed nearly 80 percent (27 out of 35) of all the M1A1 Abrams tanks and Bradley Fighting Vehicles lost in combat. This fact is much more telling given that Iraqi cannon fire could not even penetrate American tanks.

With the presence of all the new technologies available with sensors and electro-optics, the primary means of identifying armored vehicles during Desert Storm was still visual. The ultimate decision on whether a vehicle was a friend or a foe was still made by the human being. The ability of the human operator to make these decisions varied greatly. Each situation involved a number of perceptual and cognitive factors that greatly influenced the decision which was made. Training for vehicle identification has always focused on identifying U.S., allied and "threat" vehicles by predominant features or silhouettes. A search for better methods to perform this training and the need to gain greater insight into the requirements on the human being is essential. As the incidents of fratricide which occurred in Operation Desert Storm showed, improving human performance in vehicle recognition has the ultimate human factors implications: life or death.

Chapter 2

LITERATURE REVIEW: FACTORS AFFECTING ARMORED VEHICLE RECOGNITION

2.1 Human Information Processing

Wickens (1984) described a model of the stages of human information processing in detail (Figure 1). Examining each stage of the provides insight into how the overall model operates and its implications for scene recognition.

A physical stimulus presented to the sensory receptor is transformed within the retina of the eye into the appropriate neural signal. In the case of a visual input the physical stimulus is stored in short-term visual sensory stores (SSTS). This veridical representation, preserving original scene details, is stored in the form of an iconic representation. This iconic representation is then perceived. Attentional resources are required following the SSTS for processing to occur efficiently. Attention chooses the information to be processed and is a resource of limited availability. There are a number of top-down processing factors which influence the perception of the representation.

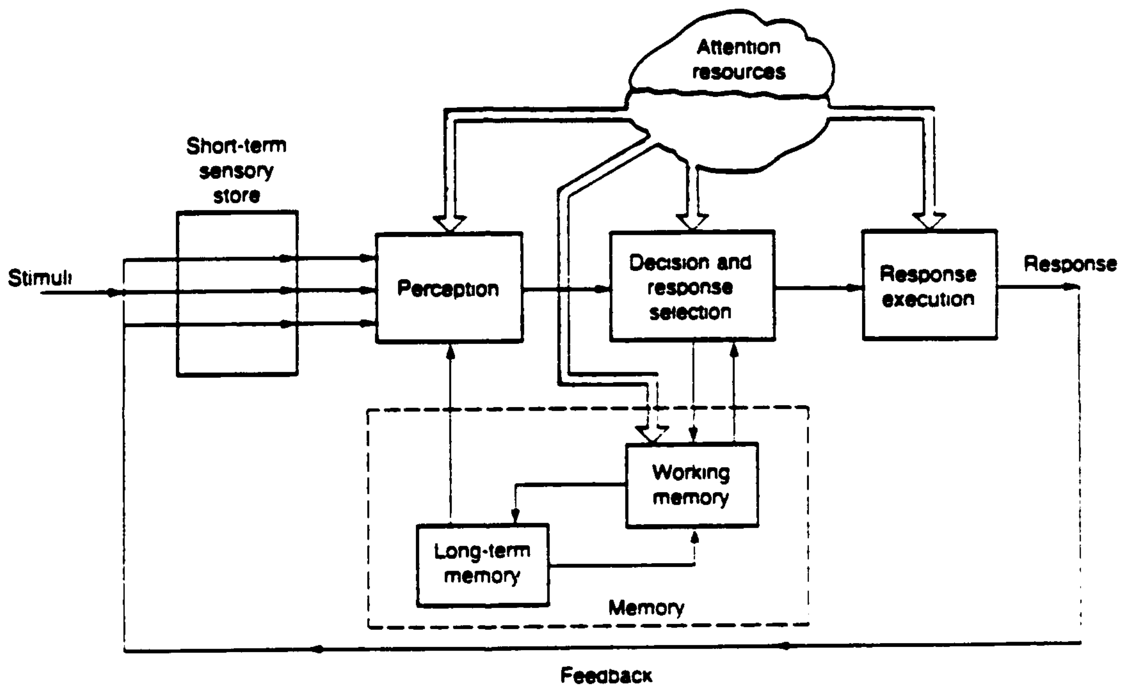


Figure 1
Human Information Processing Model
Source: Wickens, 1984

Top-down processing results from the observer bringing knowledge to a perceptual event. This knowledge can influence how a stimulus is perceived and whether the perception is correct or incorrect. The knowledge of what is being perceived, as stored in long-term memory, strongly shapes what parts of the stimulus are further processed. These selected parts are then transferred to short-term working memory. In working memory, the visual representation is matched against stored representations in long-term memory. Recognition decisions are made when this new stimulus adequately matches a representation. The point between decision making and response execution is a critical junction in the sequence of information processing. The decision to initiate the response is separate from the execution. Once this match occurs, response execution follows. At this point the cognitive process shifts to a physical output.

A similar model on human information processing and the relationships within the processor was developed by Card, Moran, and Newell (1986). The model, like the one Wickens presents, is based on a systems approach to information processing. There are three subsystems in the model: (1) the perceptual system, (2) the cognitive system, and (3) the motor system. This model outlines the time durations that occur within each of the processors. The perceptual system consists of sensors and the associated buffer memories. The most important for visual information is the visual image store in working memory. Representations within the visual information store will decay within about 200 ms (with a range of 70-1000 ms). After this decay time, less than 50% of the information in the visual information store can be retrieved. The implications for testing are that the longer a subject takes to respond to a visual stimuli that is no longer present, the less this information is available. Within the perceptual processor, information about the physical world is translated into internal representations. Within the perceptual processor, the cycle time is approximately 100 ms. This represents the time from when the image strikes the retina, is available to the visual information store, and the human claims to see it. These representations are then passed to the appropriate image store in working memory. The cognitive systems receives these coded internal representations from the sensory stores in working memory and matches them to stored representations in long-term memory. Once decisions are made the motor system carries out the response. This model of the human processor is shown in Figure 2.

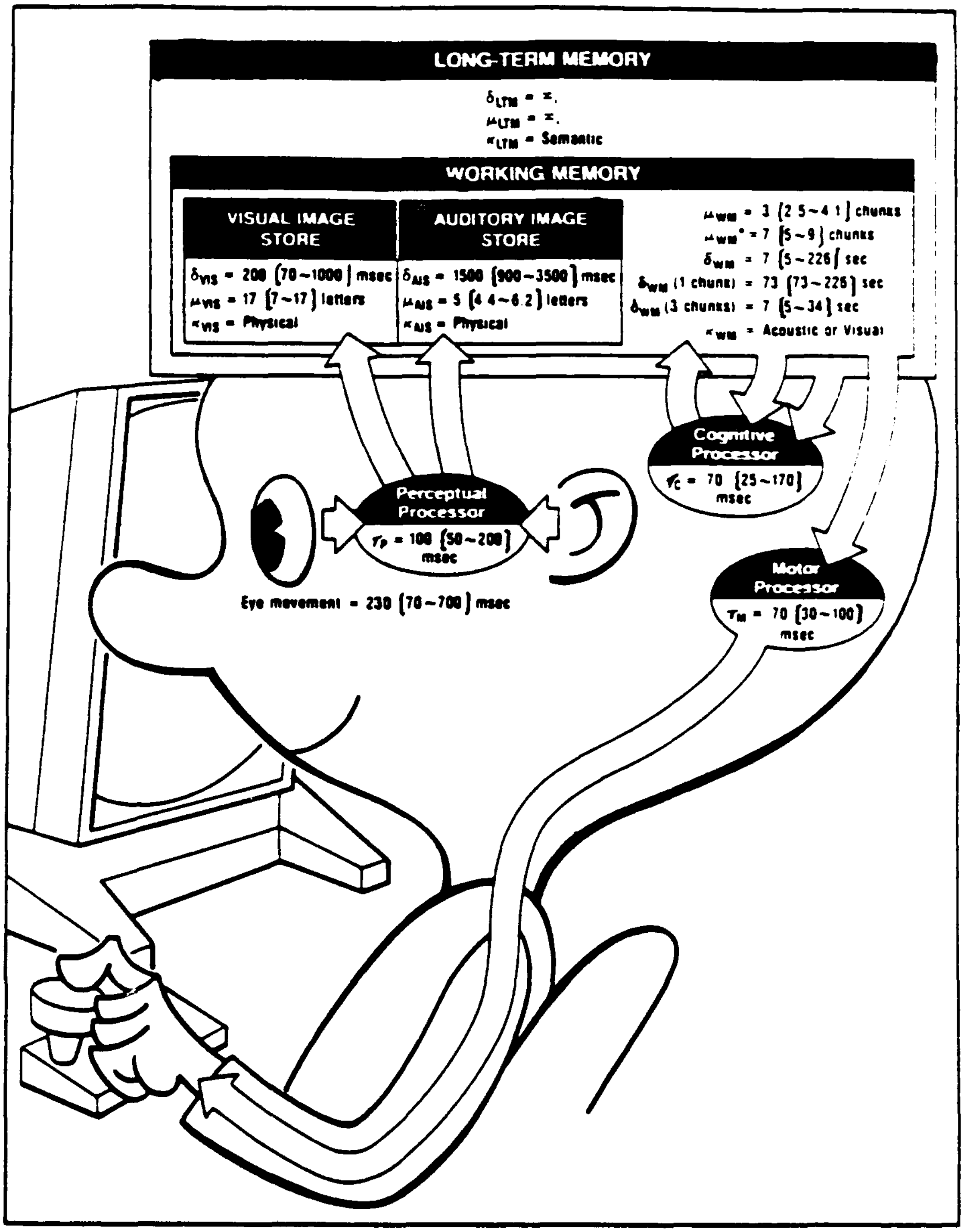


Figure 2
Model Human Processor
Source: Card, Moran, and Newell, 1986

2.1.1 Processing Models

Card et al. noted that the processing of information is not strictly mechanistic activity. Some tasks require the human operator to behave like a serial processor while others allow the human operator to process information in a more integrated and parallel fashion.

In performing serial processing, the observer compares one component of the stimulus object at a time. In this case the greater the number of components, the greater the time required to process the stimulus. The serial exhaustive memory scan requires the observer to scan a positive set and match what he is observing against it (Sternberg, 1969, 1975). According to the serial exhaustive search model, a memory scan of the positive set is made in a sequential fashion, with each comparison of the stimuli resulting in either a match or mismatch of the positive set. Sternberg identified the time of each comparison as being a finite and constant. Reaction time increases in a linear fashion based on the increase in set size. Using digits, Sternberg found the comparison time to be about 38 ms per comparison. The positive and negative response functions will result in equal slopes in the exhaustive search model.

When parallel processing occurs, all of the components can be processed simultaneously. The effect on processing time in the case of parallel processing would be that the RT values would remain constant regardless of the number of components or elements being processed. There are a number of variables that can enhance parallel processing. Information that is within 1 degree of visual angle of a focused target will receive parallel processing (Broadbent, 1982). Another example of parallel processing was demonstrated by the Stroop effect. When asked to respond to color words (e.g. blue) with different color ink, subjects showed a response conflict when the word and ink were not the same. When the word and ink were the same there was a redundancy gain (Keele, 1972). Stimuli that have the same implication for action show a redundancy gain.

During a study of armored vehicle recognition, Johnson (1981) felt the recognition task was similar to the modern view of choice information processing. He felt it is relevant to the acquisition task to view the process as a serial exhaustive memory scan. During this study, Johnson presented 12 subjects a positive set consisting of four NATO origin vehicles (M60A1, M551, AMX-30, Leopard) which were identified as the positive set. A negative set of four Warsaw Pact vehicles (T62, T55, T10, PT76) was also used. The subjects responded to the vehicle as part of the positive set or negative set. Reaction time was the dependent variable. The results showed that the slope of the function relating RT to set size was .17 seconds for both the positive and negative set; meaning that the larger the set was, the longer the choice took.

2.1.2 Signal Detection Theory

One of the outgrowths of information theory is Signal Detection Theory (SDT). This complex psychophysical procedure, allows the expression precisely and quantitatively of what information is contained in a stimulus (Green and Swets, 1966). By defining a stimulus's information, the upper limit of the observers performance can be determined. With this upper limit determined each observer's performance can be measured against a theoretical perfect observer who would use all the information available. Geisler (1989) used this technique to determine information loss in the psychophysical analysis of the stages of visual processing. Other applications have involved radar contacts (Mackworth, 1948), and detection of abnormalities on X-Rays (Parasuraman, 1980).

SDT can be applied to any perceptual activity in which there are two or more discrete "states of the world" (Wickens, 1984). These two states of the world are termed as signal and noise. The stimulus is presented and the observer must make a "yes" or "no" determination on whether the stimulus was the designated signal or not. The relationship between the presence of a signal and responses is summarized in Table 1.

Table 1
Signal Detection Definitions

Signal Status	Response	Definition
Present	Present	Hit
Present	Not Present	Miss
Not Present	Present	False Alarm
Not Present	Not Present	Correct Accept

As Table 1 shows, there are four possible outcomes in signal detection theory. Correctly identifying a signal as a signal is a "hit." Incorrectly identifying noise as a signal is termed a "false alarm." Correctly identifying noise as noise is termed a "correct reject." Finally, failure to recognize a signal as a signal is a "miss."

An SDT experiment provides at least two independent measures of observer performance. The theory uses Hit Rate (HR) and False Alarm Rate (FAR) to calculate to normalized measures. One measure d', reflects the observer's sensitivity or sensory capacity for the particular stimulus. This measure is the absolute sensitivity of the observer. The d' is a relationship between HR and FAR. Some examples of different d' values are seen in Table 2.

Table 2
Signal Discriminability (d') for Various Tasks (Craig, 1984)

Task	Estimated d'
Sonar Operation	2.0-3.0
Glass Inspection	1.4
Solder Inspection	4.1

A "rule of thumb" for interpreting d' values with task difficulty levels reveals d' value levels of <1.5 are very difficult and >3.5 are very easy (Craig, 1984).

The other measure, Beta (β) reflects the observer's criterion for acting on the information provided by the stimulus. While d' is an absolute, Beta is relative can be manipulated within an observer by instructions, costs and payoffs, and relative probabilities. The criterion can be expressed as an Optimal Beta (β*). The β* is an evaluation of the probabilities of signal and noise with the additional factors of the values gained and costs of the decision. A β^* of 1 would represent the situation where the values and costs are the same.

2.2 Tank Recognition

The most important requirement for analyzing a problem is to understand what the boundaries of the problem are. The concept of recognition differs from other aspects of visual performance on the battlefield. Recognition is simply determining whether the vehicle is friend or foe. This differs from acquisition or identification of the same vehicle or object. Acquisition is simply determining the presence of a vehicle. The identification task is a step beyond recognition. Identification requires determination of the specifics of the vehicle (i.e. nationality, model, etc). These relationships can best be seen in the conceptual model developed by Maxey et al. (1976, Table 2). This model outlines the entire process through which the armored vehicle crewman would follow during a typical tank versus tank engagement on the modern battlefield. Using this model as a guide, it is clear that the recognition task provides the critical middle phase between acquisition and identification.

Table 3
Target Acquisition Process Model (Maxey et al., 1976)

I. Surveillance and Search

II. Detection

III. Target Determination
  a. Classification (Type)
  b. Recognition (Friend/Foe)
  c. Identification (Vehicle name/number)

IV. Target Engagement
  a. Primary Fire Commands
  b. Subsequent Fire Commands

V. Acquisition of a New Target

The initial decision of whether to engage a target or not begins with recognizing it as friend or threat. If a failure occurs in the recognition task, it can set in motion a series of events which result in a "friendly fire" (fratricide) incident.

Recognition requires the observer to make the simple choice of friend or foe. When attempting to identify a tank, the number of choices increases dramatically to include type of vehicle, nationality, etc. The amount of detail required in the vehicle recognition task are primarily global in nature. Going beyond this to the next step of exact identification usually requires more than simple global representation unless the global parameters are so unique that they are unmistakable.

In recognition memory, one does not assess the correctness of a decision is not assessed. Rather one makes a decision concerning whether or not a physical stimulus "matches" a trace in the memory (Wickens, 1984). Memory load is required to match a stimulus to a trace in the memory. The observer must have a clear and defined knowledge of what the positive set is composed (Jung and Goldberg, 1987). Any observer in the vehicle recognition task then must have an established knowledge of what will be both friend or foe.

* * *

It is predicted that SDT will be able to provide an indication of human processing performance. The d' will not be any better for whole vehicle views than for turret-only views. The flank view d' will be higher than for frontal views. The Beta will be cautious.

2.2.1 Image Representations

The form in which the image is presented to an observer effects how well an object is recognized. A full three-dimensional image is not always the best way to present an image. In some situations a simplified line drawing is as good as if not better than another more detailed type of image. In a comparison of professionally photographed color images and simplified line drawings, recognition mean reaction times and error rates were similar between the two type of stimuli (Biederman and Ju, 1988). Both of the stimuli were presented at various presentation time to the subjects. The subjects then had to correctly identify the stimulus. The similarity of the resultant reaction times and error rates strongly supports the view that initial access to a mental representation of an object can be modeled as matching a edge-based representation of a few simple components. These edge-based representations are sufficient for initially accessing a stored mental representation. Similar results were determined in other studies by Ullman (1984), Biederman (1987), and Witkin and Tennenbaum (1983). Recognition, at least on the most basic level, is based on a edge-based or contour representation of an object. Studies of complex figures have shown that the nuances which are not adequately perceived or retained are internal details, within an outer contour. The fact that the internal details of the figure are not retained as well as the edge-based features is significant (Rock, Halper, and Clayton, 1972). With equal levels of resolution, there is no difference in recognition performance between black-and-white photographs, complex, embellished line drawings, or unembellished line drawings (Nelson, Metzler, and Reed, 1974). The initial access to an objects stored representation can be sufficiently activated by edges alone. This was confirmed again by Pezdek et al. (1988) when they compared simple and complex pictures. Recognition sensitivity (d') was greater for the simple pictures (2.03 versus 1.18). The expianation was that simple pictures more readiiy access the representation encoded and retained in memory. The elaborative information in complex pictures was not needed to activate the stored representation. The elaborative details appeared to be more difficult to retrieve. The initial access is strongly determined by simple representations of the image.

The discussion of which patterns or features are actually critical to a recognition task is open to debate. Krause (1965) develops a fairly comprehensive list that is shown in Table 4. This list provides a number of perceptual factors that impact on visual performance. When the observer is searching for a target on the battlefield, there are many factors which influence visual tasks. Most, however, influence the initial acquisition (detection of the presence) of an object. Once the object is located, recognition is required.

Table 4
Critical Patterns and Features (Krause, 1965)

- Target Size
- Target Shape
- Target/Background Contrast
- Field Location
- Target Orientation
- Edge Gradient
- Target/Contour Complexity
- Display Resolution
- Texture
- Brightness
- Atmospheric Attenuation
- Display Size
- Number of Confusion Objects
- Signal-To-Noise Ratio
- Display Illumination
- Presentation Mode

In recognition, the observer relies mostly on the factors which provide the most basic qualities of the object: size, shape and edge gradient. These activate the initial access required to match the stored mental representation.

There are very powerful criterion effects involved during the recognition task on the battlefield. Because of the extreme costs from which an incorrect recognition could result, the observer has a very strong bias to identify a vehicle as a foe if any doubt exists. In a tactical situation there is also a strong top-down or conceptually driven process. Decisions previously made or information already stored in memory influence perception (Bobrow and Norman, 1975). There is a great deal of uncertainty on the battlefield and based on training, a gunner naturally expects anything in front of him to be enemy. The perception of what he sees is strongly shaped by this knowledge. This requires the context of the recognition task to be more fully understood in order to make the correct decisions at the critical times.

* * *

It is predicted that line drawings emphasizing the edge-based features of the armored vehicles will be sufficient to access the memory trace in long-term memory.

2.2.2 Selective Attention

Attention can be defined as the selective aspect of perception and response and is on the basic perceptual level (Treisman, 1969). One of the key factors contributing to the recognition of an object is attention. For an object to be recognized, attentional resources must be directed towards it. Treisman accepts the concept of a number of different perceptual analyzers, each providing a set of mutually exclusive descriptions for a stimulus. Judgements about different dimensions and/or components appear to be made independently with little or no interactions supporting the concept of separate analyzers.

The direction of attentional resources toward a specific processing stage can be described using a searchlight metaphor. Everything that falls in the searchlight beam is in the consciousness for that time (Wachtel, 1967). Within the context of the searchlight metaphor for directing attention, the direction of the searchlight beam is guided by an internal model (Wickens, 1984). The channels that are sampled are selected because of the observer's model of the statistical properties of the environment. Selective attention can take the form of four functionally different types: the selection of outputs of perceptual organizers, the selection of which inputs to analyze, the selection of the type of analyzers, and which tests to make and which targets to identify. The type of attention most relevant to this study is the selection of which inputs to analyze. In the selection of inputs, the type of attention defines the information looked for. The items are identified by critical features. "Filter theory" is the term used to describe how attention can be applied to particular channels of information (Broadbent, 1958). Sperling (1960) asked subjects to report whole or partial sets of letters presented tachistoscopically on the basis of their position in the display. Since the same analyzers would be used for many of the letters, it would appear logical that the fewer the letters the better the results. The subjects reported a much larger proportion of the selected subset than of the total display. Here the selective cue must have affected the perception. The different cues did not show the same increase in accuracy of the report.

Increased evidence supporting the selective process of viewing was developed by Neisser and Becklen (1975). The basis of their study was that a perceiver can pick up certain information about an object and use it to construct a representation. Noncritical information will not be used to recognize an object (Neisser, 1969). In Neisser's study, subjects looked at two superimposed video screens, on which two different scenes were occurring. The objective was to attend to the action of one scene and to ignore the other. Subjects had little difficulty in following a given episode to which they were to attend, even with another episode superimposed over it. When attending to one scene and ignoring the superimposed episode, only 3% of the targets were missed. These results indicate that an observer can attend to specific critical events while ignoring others. One event is perceived because attention is selectively applied to the relevant information while the other information is ignored. These findings are particularly relevant to a recognition task in which the observer can pick a single critical element for recognition and ignore the other less informative elements. In the current armored vehicle recognition study the critical element is the turret.

Rabbitt (1964, gave further evidence to the ability of observers to identify certain symbols while ignoring others. In a comparison of cue sampling, subjects were required to sort cards into piles based on the presence of relevant letters on the cards among irrelevant letters. The subjects consisted of 12 male undergraduates and 4 members of the Royal Navy. The results indicated that the learning of specific cues results in the ability of the subjects to rapidly sort the cards. These results give further evidence to how effective it can be to selectively attend to a specific cue or feature during a search task.

* * *

It is predicted that the subjects will be able to selectively focus their attention on a single component of the armored vehicle. Since the most dominant feature on the vehicle is the turret, the subjects will selectively focus their attention on the turret and use it for the primary recognition of the vehicle.

2.2.3 Eye Fixations and the Locus of Attention

Areas of unusual details and unpredictable contours received more fixations than areas of redundant information and areas of mere texture received very few fixations (Mackworth and Morandi, 1967). Perception is not passive sampling, it is interlocked with memory to the extent there is no perception without recognition (Hake, 1957). Vision systematically selects parts that lead to the greatest coherence. During their study, Mackworth and Morandi used 20 subjects and determined their visual and verbal choices of the areas of relative importance in the stimulus pictures. Visual choices were recorded using a photograph by a stand eye-camera of fixation locations. Verbal choices were based on a subjective rating of the importance of each portion of the stimulus photograph. The stimulus photograph was divided into 64 squares of equal size. A few regions in each of the pictures dominated the data. As may as 60% of the fixations fell on just 10 squares, that is two-thirds of all fixations on just about one-tenth the area. Fixations were occurring at a rate of three fixations per second. The areas to which the fixations were directed were those in which the contours were unique and unpredictable. The subjective evaluations of what the subjects deemed important strongly indicated that contours were more valuable than any other type of info provided by the pictures.

Certain areas of a photograph will receive very high informative ratings while others were ranked very low. This combination of eye fixation readings and subjective evaluations continues to support the edge-based argument for recognition (Pollack and Spence, 1968). The contours (edges) of objects shown within a picture received the highest subjective ratings and provided the most information and therefore attracted the most attention. Most of the informational content occurs at locations of contour changes along the edge of a drawing (Attneave, 1954). Mackworth and Morandi concluded that peripheral vision edited out predictable contours, as well as areas of smooth texture. Fixations occurred very rapidly in all the informative areas, within the first 2 seconds of viewing the scene. The critical finding is that there are areas within a picture that dominate the attention of the observer and allow recognition without fully viewing all areas of the picture.

In attempting to measure how and when fixations occur in a scene, Loftus and Mackworth (1978) measured fixation location and duration when subjects viewed a specific scene. Their results support the previous studies in that they found that observers fixate earlier, more often, and with longer durations on certain informative areas of a scene. In this study, 12 subjects were required to view 78 separate pictures. The eye movements were recorded using a digital, pupillary-reflection camera. Informative objects, those with a low a priori probability of being in the picture, were found faster. The advantage of informative over noninformative was significant by a sign test ($z=2.54$, $p<.01$). With respect to the subjects, 8 of 12 subjects fixated the informative object earlier. The advantage of informative objects was again significant ($t(11)=1.80$, $p<.05$). Fixation also tended to be longer on the informative objects ($F(1,11)=8.23$, $p<.05$). The authors suggest that during a recognition task, attentional allocation is related to memorization strategy. Since recognition requires separating the object from other similar objects in memory, the most efficient strategy would be to encode those areas that are least likely to appear in the other similar objects. It is these objects that would be the most informative. The implications for the armored vehicle recognition task is that of all the features on a tank, those that have the lowest degree of similarity are the turrets. Using the results from Loftus and Mackworth, it is proper to assume that the turret would receive earlier and longer fixations. Recognition by this single component would not be impossible.

* * *

It is predicted that tachistoscopic presentations will require subjects to fixate on the most informative areas. This most informative area will be the turret.

2.2.4 Impact of Components and Parts

Observing armored vehicles on the battlefield presents the observer with a large number of viewing situations. Because of terrain and the effects of dust and smoke the observer rarely can see the entire armored vehicle. Most of the vehicle can be obscured and the observer must make many recognition decisions seeing only one or two parts of the vehicle. A detailed analysis of vehicle recognition requires a fuller understanding of how parts and components effect recognition on the battlefield. On the battlefield, the recognition decision must be made quickly. Entire engagements between two vehicles can last much less than 10 seconds. Within this 10-second interval the target must be acquired, the gun system loaded and aimed at the target, and the weapon fired. The gunner has very little time to try and determine exactly what a vehicle is. Complicating this task is a great deal of environmental factors such as dust and poor illumination.

There are two views on how an observer will view an object. One view is that the overall shape of the vehicle must be taken into account when performing this task. The other view holds that each element has some value to overall image viewing and must be viewed as critical. At one extreme is the structuralist position that the perception of whole figures is nothing more than the concatenation of primitive perceptual elements. At the other extreme is the Gestalt position that the perception of whole figures is an indivisible entity whose properties are not determinable from the properties of their components. The key elements of form and structure will have a great impact on how an observer views the object.

A theoretical framework that synthesizes the holistic and structuralist approaches to recognition can be developed (Palmer, 1977). At each level in a hierarchy, structural units are defined as a set of global properties and atomically as an organized set of parts. These parts are the structural units at the next-lower level in the hierarchy. The structural units are considered to be analogous to Miller's (1956) construct of chunks. This concept results in the development of a hierarchal structure of parts and wholes, each of which has a representation of holistic properties as well as component structure. Using simple straight-line figure combinations as stimuli, Palmer examined the parsing of figures, part goodness, and part verification reaction times. The results of his experiments strongly indicate the importance of selective organization in perceptual representation and processing. Parsing appears to follow the Gestalt claims of natural groupings. The subjects were generally able to be identified perceptually as "triangle finders" or "box finders." This is because of the familiarity of triangles and boxes as frequently used parts and because their segments are highly compact. The evaluation of part goodness showed significant differences in goodness of sub-elements within the same figure. The result demonstrates that the goodness of a part depends not only on the properties of the part itself, but also on its relationship to other parts in the same figure. Reaction time evaluations of part probes revealed that part goodness was a key factor in allowing the subjects to respond more quickly. Positive responses to good part pairs were 500-600 ms faster than for bad parts. This clearly showed that perceptually a good part is processed and recognized faster than the bad part, as if good parts are processed in a qualitively different way from bad parts. Perceptual processing therefore has a strong component that emphasizes parts of figures as a key to processing a visual image.

The key role that parts plays at the basic level of perception was examined by Tversky and Hemenway (1984). Parts underlie various empirical operations of perception, behavior, and communication that converge at the basic level. With respect to perception, parts influence the ultimate shape of larger objects. Using Rosch et al. (1976) in which basic level categories were found to have the most recognizable shapes, Tversky and Hemenway developed a series of studies in which they examined the impact of basic level categorizations. Subjects were required to develop attribute lists of general categories of objects. At the basic level, over 52% of the attributes for an object were parts. The general processes for recognizing an object are based on the parts that the object is composed of. In all cases at the basic level, parts were more predominant than other features, such as colors, for developing a taxonomy for an object. An analysis of a good part resulted in most subjects agreeing on the goodness of the parts presented. The parts presented were common objects such as furniture and clothing. Subjects responded by listing the parts and identifying which parts were good.

Functional significance seems to play a key role in the subject's goodness rating. The best part of the chair was the seat, the best part of the pants were the legs, etc. A case can be made that the best part is the most perceptually obvious and functionally the most important. This is important for the current study where the importance of the turret in recognition of an armored vehicle is being examined. The turret is both the most perceptually obvious feature on the armored vehicle and the most important component functionally. The turret's location makes it stand out to an observer. The hull and the suspension system appear as a single solid mass, particularly at greater distances. The turret is the component that stands out most because it is distinctively separate from the combination of the hull and suspension. This should give the turret a high goodness rating among the parts. The way forms are parsed into parts by geometry and or surface appearance plays a role in how the parts are recognized and processed. Parts parsed through local minima in contour or wholeness appear to influence how they are recognized. These parts appear to be better cues to memory for the whole form (Bower & Glass, 1976); they are more quickly identified as being part of the whole (Palmer, 1977). These two points provide evidence that the part can be used to recognize the whole just as efficiently and also possibly more rapidly. Further evidence indicates that in the task of object recognition, the visual system decomposes shapes into parts. It does so using a rule defining part boundaries rather than part shapes. Parts with their descriptions and spatial relations provide the first index into a memory of shapes (Hoffman and Richards, 1985). Simple line drawings are sufficient because the visual system exploits the regularities of nature in two ways: they underlie the mental categories used to represent the world and they permit inferences from impoverished visual data descriptions of the world. Parts are useful because the image rarely presents its entire form for view. The rear is almost never present, yet objects are recognized based on the number of parts available. Using a minima rule, parts are divided along contours of concave discontinuity. Hoffman and Richards (1982) examined the importance of parts in terms of the development of artificial intelligence, parsed parts along the lines of geometry or wholeness have played an important role in the structural descriptions of objects. Tversky and Hemenway conclude that when people think about entities at the basic level, parts are the critical information.

Parts are the key element that are structured in order to comprehend, infer and predict function.

* * *

It is predicted that a single component is sufficient to recognize a total object if the component is critical. The turret is this component on an armored vehicle. The turret stands out from the other components of the vehicle.

2.2.4.1 Theory of Recognition by Component

One of the more recent attempts to explain how humans perceive objects has been proposed by Biederman (1987). In his theory of Recognition-by-Components (RBC), the perceptual recognition of objects is conceptualized to be a process in which image input is segmented at regions of deep concavity into an arrangement of simple geometric components. In order to support this theory, Biederman developed a schematic model of the presumed subprocess by which an object is recognized. This model is shown in Figure 3.
The early edge extraction stage provides the line drawing description of the object. The parsing of this image is performed primarily at concave regions. Concave regions are those in which the line of the part or component turns inward. These parsed regions

provide the components critical to initial access to stored mental representations. The stages up to and including the identification of components are a bottom-up process. Beyond that, the arrangement of the components is matched against a stored representation in memory.

The fundamental perceptual assumption of RBC is that the components can be differentiated on the basis of perceptual properties in the two-dimensional image that are readily detectable and relatively independent of viewing position and degradation. These perceptual properties include: good continuation, symmetry and regularity. The components that are parsed out of an object have been called "geons" by Biederman. There are about 36 of these geons in RBC and they supposedly can be derived from the readily detectable properties of edges in two-dimensional images. This again stresses the importance of edge-based detectors as a key to successful recognition.

Biederman presented a series of trials in which subjects were verbally recognized an object after a 500ms presentation of various numbers of the components that made up the object. Error rates were reduced when more components were shown. Error rates overall were modest.

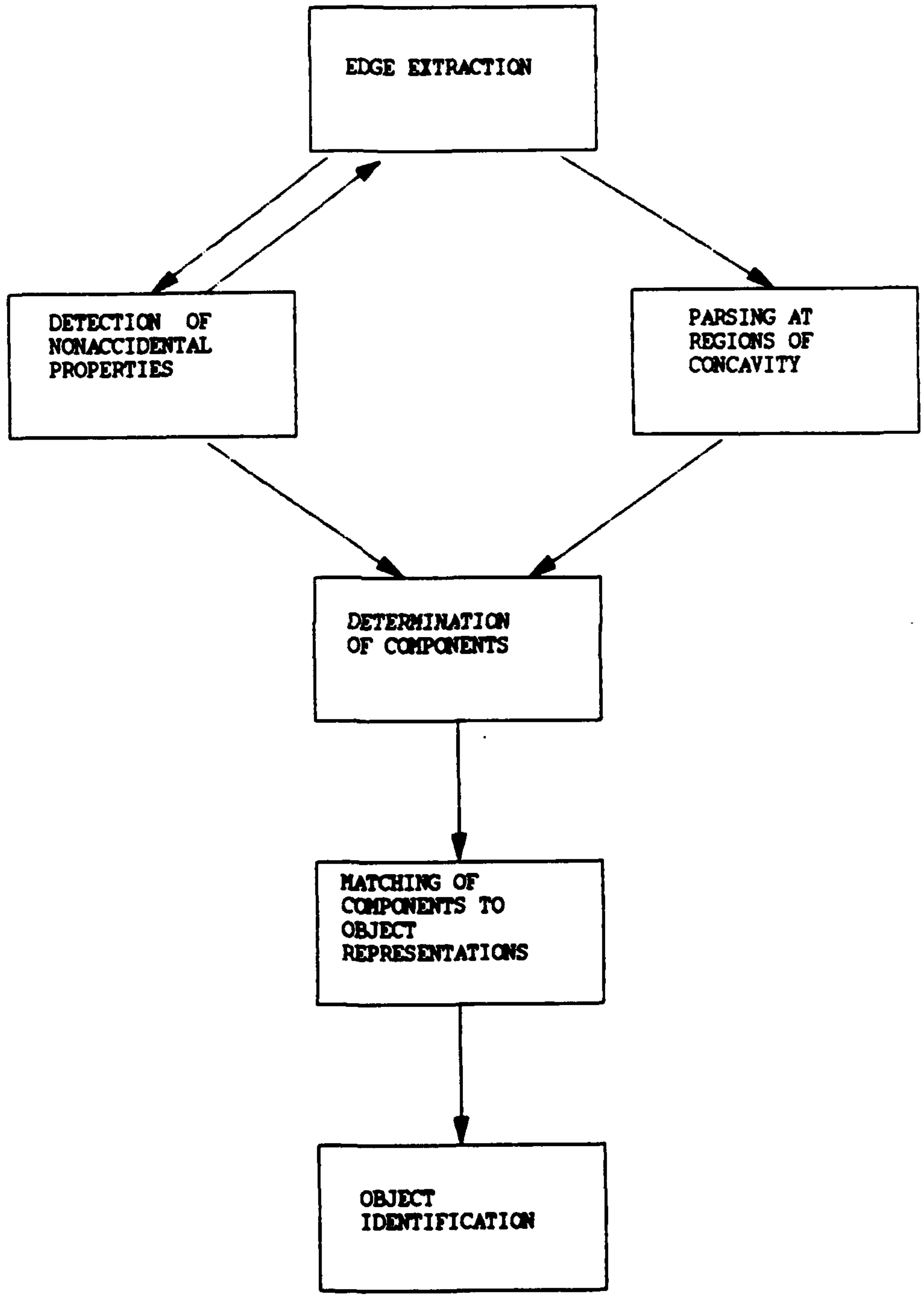


Figure 3
Processing Stages in Object Recognition
Source: Biederman, 1987

When objects that had six to nine components were presented, accuracy rates above 90% were obtained when only three or four of the components were presented. Mean correct RTs showed the same trend.

Initial access to a mental representation could be: (a) gained with only the presentation of only a few components even with brief exposures, and (b) line drawings were sufficient to activate this mental representation. When components are in their specified arrangement and they can readily be identified, object recognition will be fast and accurate (Biederman, 1987).

It is important to recognize which component is the critical feature of the vehicle. This would permit the development of a mental strategy for viewing. The detail of an image must be sufficient to represent the vehicle's critical features, but not so much as to add undesirable complexity to the image. The critical features (or distinguishing features) of an armored vehicle can be as global as turret shape or hull shape, or may be as local as the position of the bore evacuator on the gun or the position on smoke grenade launchers on the turret (Kottas and Bessemer, 1981). Two facts with armored vehicles have been revealed. First, in viewing an armored vehicle, flank or oblique views provide the most information because a larger number of the critical features are able to be viewed. The flank and oblique views present a larger visual cross-section and therefore provides a greater number of cues on which to base the decision. Second, in a combat environment at and beyond 3 km, the critical features that provide reliable information are: turret shape and location, the main gun and fender skirts (if any). Using scaled ranges and vehicle models, Kottas and Bessemer found that these critical features were the only ones that could be reliably seen at the extended ranges which would occur in combat.

* * *

It is predicted that when only the turret is seen, RT and accuracy rates will be the same as when seeing the whole vehicle.

2.2.5 Complexity

Complexity is a critical issue when viewing an armored vehicle. By its very construction, the armored vehicle represents an object that is composed of many sub-elements and parts. The complexity of the armored vehicle appearance is increased by a number of additional factors such as camouflage paint patterns. The complexity of a figure impacts on how that figure is processed and therefore on subsequent performance of any memory recall task. All patterns, regardless of what they are, possess some degree of complexity. The key is to what extent that complexity aids or hinders in the recognition task. The determinants of pattern complexity can be separated into quantifiable variables (number of turns, amount of contour, and horizontal and vertical symmetry). This establishes an upper bound on complexity. When subjects were required to look at a stimulus of 6 X 6 matrices of black and white squares, each with 12 black squares. Each subject was required to subjectively provide a magnitude estimation of the complexity of the pattern presented. The patterns were judged more complex if there were a greater number of turns or corners, greater area, and less symmetry (Chipman, 1977).

More complex figures do not establish adequate mental representations in memory. When a subject was presented a complex figure and then required to select the same figure from a sheet containing the figure and a number of similar figures, the more complex the figure, the less the ability to recognize the figure (Rock, Halper, and Clayton, 1972). Figures with an outer contour alone were seen and recognized better than those with additional lines enclosed in the outer contour. With a single exposure it is the components of complexity such as interior contour and slight variations in exterior contour that are not remembered. Applying this to the image of an armored vehicle, turret shape would be remembered while some of the details such the presence of smoke grenade launchers, vision blocks, etc., should not be adequately perceived and therefore matched to a memory trace.

This is supported by studies at the United States Army's Armor School at Fort Knox, Ky. The Armor School is the primary training center for the armored vehicle crewman who must make the recognition decisions on the battlefield. The complexity of the figure detracts in recognition. Kottas and Bessemer (1980) found that when training armored vehicle recognition the use of excessive detailing produces negative results by having the observer depend upon information that will not be normally available. This is important to recognize because training with more simplistic or even single component views may be more beneficial for increasing observer performance.

* * *

It is predicted that reducing the complexity of a vehicle image will result in better performance in a recognition task. Two methods of complexity reduction used here are single component and edge-based images. The single component of the tank that will be presented will be the turret.

2.2.6 Exposure Duration

Another element that is particularly relevant to this the recognition task is how perception is influenced by viewing or exposure time. Several factors are influenced by exposure duration: First, novel figures viewed only once establish relatively enduring memories, certain nuances of more complex figures do not seem to establish adequate traces at all. Secondly, during an exposure, the characteristics of overall form and shape are the most enduring. Thirdly, recognition is superior with the fewer the number of test alternatives presented to a subject. Finally, when presented with repeated exposure to a complex figure, features would be noted on some encounters that are not noted on others so that mere repetition would lead to adequate trace formation (Rock, Halper, and Clayton, 1972). These findings indicate that performance in the vehicle recognition task can be greatly enhanced by practice, however reduced viewing time could prevent adequate trace formation. This has "real world" implications for the observer in a combat situation where the decision of friend or foe must be made rapidly. Failure to do so could result in fatal consequences.

The exact amount of exposure time required is important to understand. Reactions to a stimulus which the subject feels a degree of liking with may be acquired by virtue of experience with that stimulus even if conscious recognition doesn't occur (Zajonc, 1980). These same reactions may well play a role in how we recognize an object. During several phases of a study in which 20 subjects were presented stimuli in the form of 20 oriental ideograms, prior exposure consistently affected recognition responses more than liking responses (Brooks and Watkins, 1989). Analysis of the recognition ratings showed that prior exposure frequency was significant ($\underline{F}(4,76)=60.69$, $\underline{p}<.001$). Affect for a target could occur at very rapid exposure durations. Seamon, Marsh, and Brody (1984) reported that target selection by recognition required longer stimulus exposures and improved as the durations increase. The study had 180 subjects who viewed 20 irregular, eight-sided polygons presented tachistoscopically for durations of 0, 2, 8, 12, 24, or 48 ms. Affect judgements rose quickly with brief increases in exposure duration through the 8 ms exposure and were significant ($\underline{F}(1,97)=4.95$, $\underline{p}<.05$). Recognition judgements remained unchanged through 8 ms. Beyond that point recognition improved sharply while affection remained unchanged. For exposure durations of 12 ms or longer recognition surpassed affect

($\underline{F}(1,57)=26.48$, $\underline{p}<.05$). The results show that recognition requires a greater level of exposure duration than affect. Recognition requires that the stimulus is presented for sufficient time for the stimulus to be matched to an established trace in memory. Exactly what that exposure duration is open to question. During a study using common objects, a 150 ms flash presentation of scene allowed subjects to detect objects subtending a visual angle of 3 degrees and lying 5 degrees from fixation can be detected 85% of the time (Biederman et al., 1981). Visual information processing may be completed within the first 100 to 150 ms of stimulus exposure (Sperling et al., 1971). Teitelbaum and Biederman (1979) found similar results could be recorded if the exposure duration was reduced to 100 ms. The importance of these exposure durations indicates that since voluntary eye movements can occur at the rate of about 3 per second, exposure durations this quick would be subject to the effects of where the first eye fixation would fall. This would provide insight into what is deemed informative and draws the attention of the observer.

* * *

It is predicted that the observers will be able to recognize the vehicle with presentation times as quick as 100 ms.

2.3 Recognition Studies Dealing with Armored Vehicles

From 1980 to 1985 the Army conducted a series of studies under the title of "Target Acquisition and Analysis Training System." During this time period more than 60 research projects were undertaken in order to find ways to improve soldier performance in the area of armored vehicle recognition and identification. Some of the topics included in the study were effects of motion on performance; effects of number of vehicles trained; training frequency; soldier trainability; and cue recognition.

Warnick and Smith (1989) summarized some of the key findings from the studies:

> (1) The quality of a combat vehicle image is not a critical factor in teaching recognition provided that the critical cues (chassis shape and size, turret shape and position, and at times the gun tube) are visible. These critical cues were the ones that could be seen reliably under the various conditions that would occur in combat. Other features and cues would not consistently be present.
>
> (2) Using motion does not positively effect training.
>
> (3) Training all soldiers in vehicle

identification may not be cost-effective since some can't effectively learn the minimum standards after repeated training sessions.

The key issue for this study is whether certain features could provide valuable recognition cues. This was addressed by Foskett, Baldwin, and Kubala (1978). The goal was to determine which cues from the vehicles could be seen well enough to be used for recognition. During their study, subjects were required to walk along a scaled course viewing 20 HO scale models in an attempt to determine the ranges at which certain critical features would become recognizable. The course was set up to reflect the 1:87 scale of the models. The results indicated that a number of recognition features (e.g. roadwheels, sprocket locations, and gun tubes) were not visible until the observer was very close to the target. The features most valuable at scaled distances beyond 1200 meters were: (a) tracked versus wheeled, (b) presence of the turret, and (c) turret location and shape. These results indicate that the cues that are most valuable are those that are stable and can be recognized at long ranges. The features that are most discernable at the longer ranges are primarily global in nature (Kottas and Bessemer, 1981). Using the data obtained by

Foskett et al., the vehicle feature that provided the most recognizable cues at ranges beyond 1000 meters was the turret. The only valuable cues on the hull and suspension were the presence of fender skirts and whether tracked or wheeled, respectively. Both of the hull and suspension cues would be almost useless since a large number of both friend and threat vehicles possess these characteristics. These results strongly suggest that the turret is the most important feature on an armored vehicle and must be the one learned best in order to form a strong mental trace in long term memory.

* * *

It is predicted that by basing recognition on a single component, the turret, the result in performance will be equal to or better than seeing the whole vehicle.

2.4 Experimental Objective

The objective of this study is to examine some of the factors which influence armored vehicle recognition. Specifically, the following issues are to be examined:

(1) Will the subject perform recognition as well seeing only the turret instead of the

whole vehicle?

(2) In a time-limited presentation will the observer be able to correctly identify a vehicle based on 2-D line drawings which are primarily edge-based stimulus?

Chapter 3

METHODS

3.1 Methods

3.1.1 Subjects

Ten male subjects participated in the study. All the subjects were active duty members of the U.S. Army attending the Pennsylvania State University. The subject data is shown in Table 5.

Table 5
Subjects of the Experiment

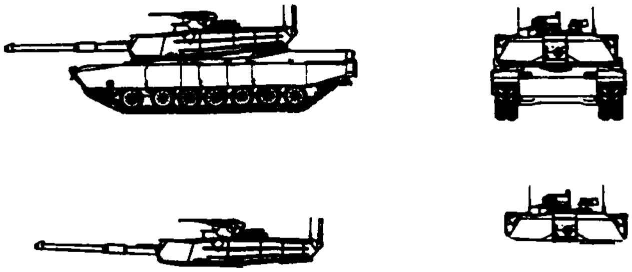
Subject	Age	Army Experience
1	30	8 years
2	31	9 years
3	33	11 years
4	33	11 years
5	31	10 years
6	33	10 years
7	32	10 years
8	33	10 years
9	31	8 years
10	30	9 years
Mean	31.7	9.6 years

The mean age of the subject was 31.7 years with a mean of 9.6 years service in the U.S. Army. A subject was screened and verified to possess either 20/20 or corrected to 20/20 vision. The subject participated in the study for a single session on a single day. The subject volunteered and received no compensation.

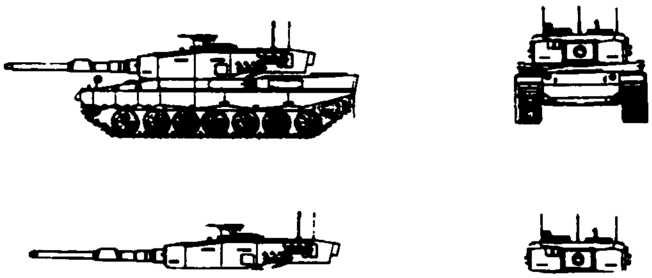
3.1.2 Stimuli

The stimuli used were six armored vehicles selected from U.S. Army Graphic Training Aid (GTA) 17-2-13. The GTA is one of the standard training aids for training vehicle recognition and identification. The vehicles appear as line drawing representations against a homogeneous white background. Three of the vehicles were from NATO nations (M1, Challenger, Leopard 2), and three were from the former Warsaw Pact (T62, T64, T72). The NATO vehicles were designated as "Friendly" and were the positive set for the study. The Warsaw Pact vehicles were designated as "Foe" and were the negative set. Each vehicle was shown from the flank or front. Each vehicle was also shown as a whole form and as the turret only. All images were on 35mm slides. The views presented for the NATO vehicles are shown in Figure 4. The views presented for the Warsaw Pact vehicles are shown in Figure 5. The stimulus was projected at a distance of 145 cm (57 inches) from the observer, at this distance the vertical height of the stimulus subtended approximately 2 degrees of visual angle.

M1 Abrams (US)



Leopard II (Germany)



Challenger (UK)

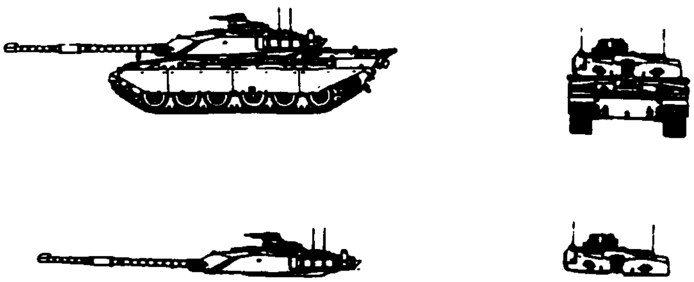
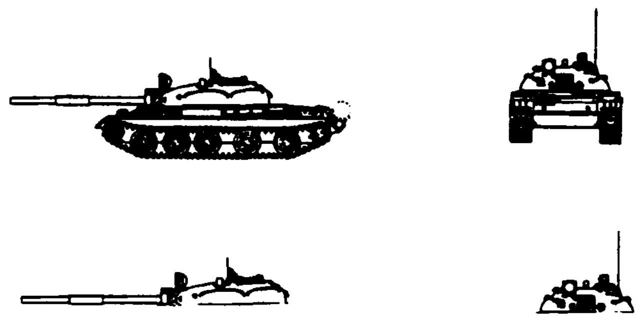
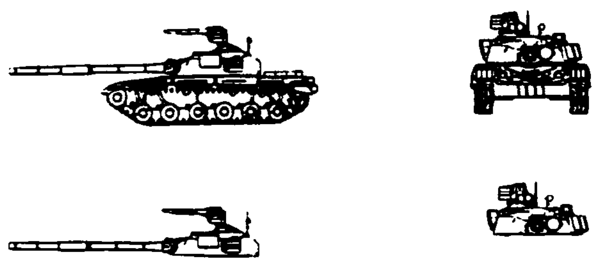


Figure 4
Friendly Vehicle Stimulus Presentations

T-62 (Soviet)



T-64 (Soviet)



T-72 (Soviet)

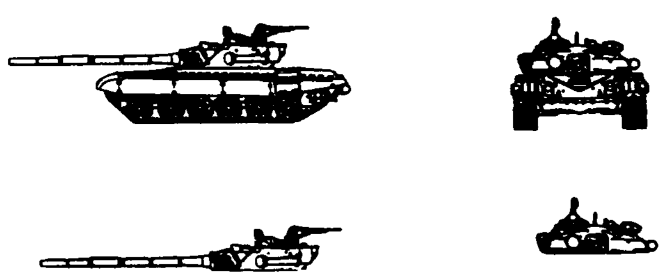


Figure 5
Foe Vehicle Stimulus Presentations

The stimulus was standardized in size relative to actual size relationships for the actual vehicles. Under these conditions, the stimulus appeared to be at an actual distance of 200 meters or about 2600 meters if viewed through 13 power optics. The 13 power optics are the standard for the TOW Heavy Anti-tank system. This weapon system is the standard for many units in the Army that would find themselves in combat against enemy armored forces. The system consists of a guided missile capable of engaging targets at ranges beyond 3700 meters and is highly lethal.

3.1.3 Apparatus

This study was performed in a laboratory environment. The apparatus used for this study included an IBM compatible 286 computer with a Quick Basic program developed for this study. The computer was interfaced to a Kodak 850H 35mm Carousel projector which was equipped with a Lafayette Instrument Co. 41010 Automatic Lens Tachistoscope. The interface between the PC and projector was designed to integrate the Tachistoscopic Lens, the PC and the Quick Basic program, and the carousel advance. The slides were projected through a rear projection screen. The response device was a Fulcrum Computer Products

Trackball. The subject responded to the stimulus slides by pushing two buttons, designated friend and foe, on the trackball. If a slide of a foe vehicle was presented, the correct response was to press the right button to register a foe response with the computer. If a slide of a friend vehicle was presented, the correct response was to press the left button to register a friend response with the computer. The trackball was held with both hands in a manner similar to grasping the gunner's controls on a tank. The thumbs were positioned on each response button as the thumbs are on the laser switches on the actual gunner's control. By pushing the thumb swithches, the response of the observer replicated the actions that the gunner on a tank would have to do if an enemy tank was being engaged. An equipment schematic showing the exact pieces of equipment used in the study and their location in relation to each other appears in Figure 6. The interface circuitry and Quick Basic program are listed in Appendices A and B, respectively.

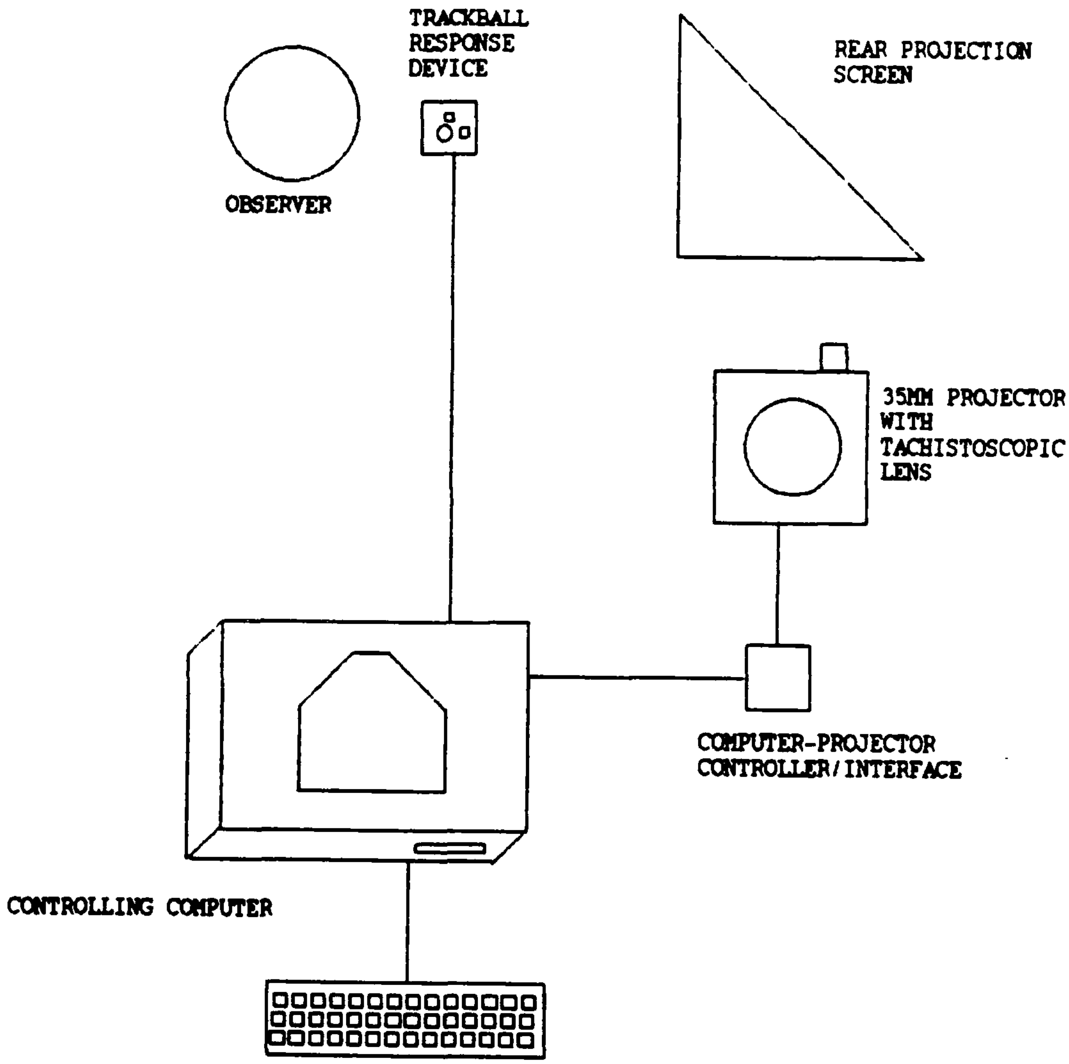


Figure 6
Equipment Layout

3.1.4 Experimental Design

The experimental design used for the study is shown in Table 6. A within subject design was adopted. The subject performed a total of six experimental blocks. The blocks were random and divided into three blocks of 500 ms presentations and three blocks of 100 ms presentations. For each block, the subject was presented 24 trial slides. The probability of either a friend or foe target was always .5. The result was a total of 144 observations for each subject.

Using reaction time, hit rate (HR) and false alarm rate (FAR) as a dependent variables, five independent variables were examined in the study. The five variables were: presentation time (500 ms or 100 ms), vehicle component (whole or turrèt), viewing angle (frontal or flank), and vehicle type (friend or foe). The model was nested within the vehicle type. This was necessary because for each level of vehicle type (friend or foe), there are three sublevels representing the specific models used as stimuli. The models of the vehicles were: M1, Leopard, and Challenger for the friendly vehicles and T62, T64, and T72 for the foe vehicles.

Table 6
Experimental Design

Presentation Time	Type	Component	Angle	Model	Number of observation
100 ms	Friend	Whole Vehicle	Front	M1 Abrams	3
				Leopard 2	3
				Challenger	3
			Flank	M1 Abrams	3
				Leopard 2	3
				Challenger	3
		Turret Only	Front	M1 Abrams	3
				Leopard 2	3
				Challenger	3
			Flank	M1 Abrams	3
				Leopard 2	3
				Challenger	3
	Foe	Whole Vehicle	Front	T62	3
				T64	3
				T72	3
			Flank	T62	3
				T64	3
				T72	3
		Turret Only	Front	T62	3
				T64	3
				T72	3
			Flank	T62	3
				T64	3
				T72	3
500 ms	Friend	Whole Vehicle	Front	M1 Abrams	3
				Leopard 2	3
				Challenger	3
			Flank	M1 Abrams	3
				Leopard 2	3
				Challenger	3
		Turret Only	Front	M1 Abrams	3
				Leopard 2	3
				Challenger	3
			Flank	M1 Abrams	3
				Leopard 2	3
				Challenger	3
	Foe	Whole Vehicle	Front	T62	3
				T64	3
				T72	3
			Flank	T62	3
				T64	3
				T72	3
		Turret Only	Front	T62	3
				T64	3
				T72	3
			Flank	T62	3
				T64	3
				T72	3

The designations of whether a response was a Hit, False Alarm, Correct Accept, or Miss, for the SDT analysis of d' and Beta, were based on the definitions listed in Table 7.

Table 7
Definition of Hit, False Alarm, Correct Accept, and Miss

Presentation	Response	Definition
Friend	Friend	Correct Accept
Friend	Foe	False Alarm
Foe	Foe	Hit
Foe	Friend	Miss

As the table shows, the key definition is that of a False Alarm. A False Alarm is critical because it would result in a potential friendly fire incident. The False Alarm results in a friendly vehicle being incorrectly be recognized as a foe. Under these circumstances, a fire command would be initiated by the armored vehicle crew. A Correct Accept is the proper recognition of a friendly vehicle as a friend. A Hit is the proper recognition of a foe vehicle as a foe. A Miss is a failure to recognize a foe vehicle.

3.1.5 Procedure

A schematic showing the within-subject procedure is shown in Figure 7. The subject participated in the study for a single session which lasted approximately 1 hour. Prior to the beginning of the study, the subject was required to study pictures of all the vehicles using copies of GTA 17-2-13. The subject was required to identify each of the vehicle pictures prior to beginning the experimental trials to eliminate any doubt that the subject knew the vehicles.

During experimental trials, the subject participated in six blocks. In each block, there were 24 trial slides. At the beginning of each block, the presentation area on the screen was shown to the subject. Three beeps occurred 1 second before each slide presentation. When the slide was presented, the subject responded as accurately and quickly as possible. After the subject responded by pushing the friend or foe button, there was a 5 second interstimulus interval before the next slide presentation. For each response reaction time and response (Friend/Foe) were recorded by the computer. At the end of each block a total of all the responses were presented, to include mean response time and the standard deviation of the response times.

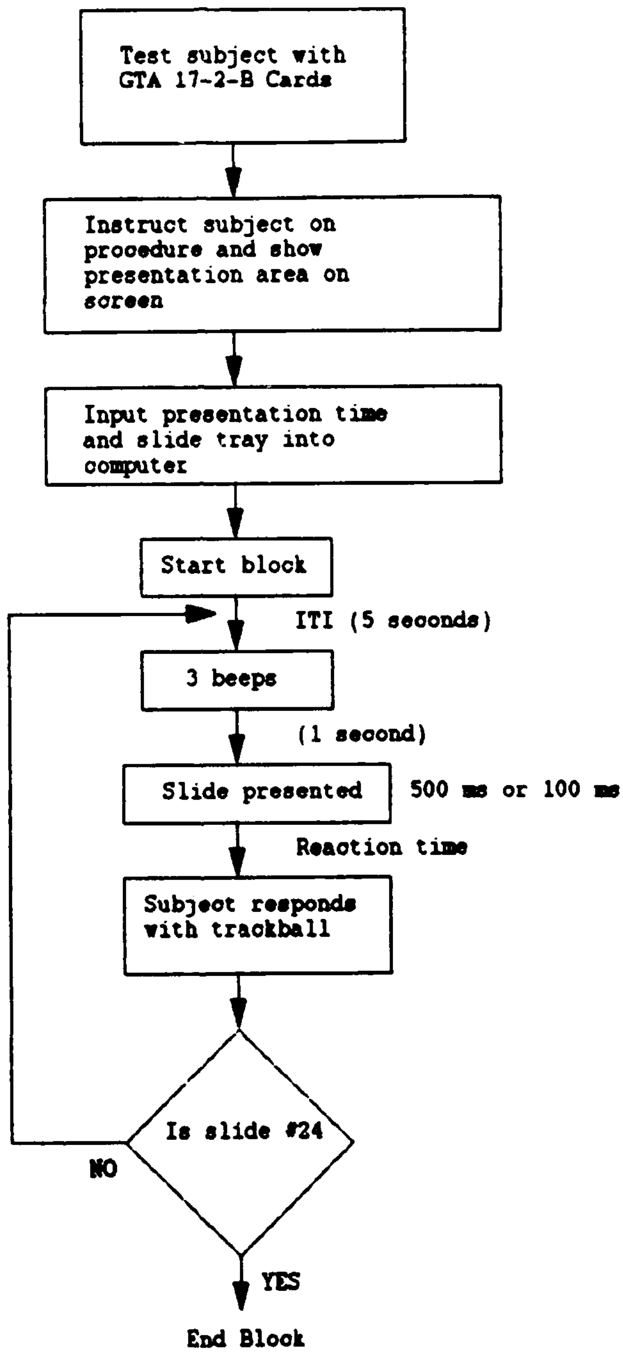


Figure 7
Experimental Procedure

Chapter 4

RESULTS

The data from the study was analyzed between- and within-subjects. The between-subject analysis was used to determine trends which may have occurred between the different experimental conditions. The dependent variables were Correct Recognitions, Mean Reaction Times, d-prime (d'), and Beta (β). The within-subject analysis was performed to determine the effect of individual differences which existed in the study. The same dependent variables were used for the within-subject analysis.

4.1 Dependent Measures

The dependent measures used in the study were Correct Recognition and Mean Reaction Time. The Correct Recognition was determined by measuring the number of correct recognitions which occurred within each cell of the experiment. Within each cell there was a possibility of three correct responses for a single subject. The number of correct responses in each cell was totaled and a proportion correct was recorded for that cell. Across all 10 subjects, the number correct for a specific cell was summed and a total proportion correct was determined. Correct responses for a friend vehicle was determined by evaluating the "Correct Accepts" for each friend conditions. A correct response for a foe vehicle was determined by evaluating the "Hits" for each foe condition.

Mean Reaction Time for each cell was determined by evaluating each reaction time associated with the correct responses in that cell. The mean RTs for friend vehicles were associated with "Correct Accepts". The mean RTs for foe vehicles were associated with "Hits". The RTs were summed and then divided by the number of correct responses for the cell. The analysis of d' and ß for the correct recognitions can reveal changes in sensitivity of the observers and any trends whicn may occur because of criterion shifts. The d' was determined by measuring the "Hit Rate" and "False Alarm Rate" for specific conditions and groupings of cells. These d' values were used to evaluate the sensitivity changes that occurred between the conditions. For each of these d' values, a ß was determined in order to evaluate the criterion changes that occurred. A summary of the experimental results are found in Table 8.

Table 8
Summary of Experimental Results

Present Time	Type	Comp	Angle	Model	P(Correct)	P(Error)	Correct Response Mean RT	SD
500 ms	Friend	Whole Vehicle	Front	M1	.967	.033	.96	.18
				Leo	.967	.033	.99	.24
				Chal	900	.100	1.07	35
			Flank	M1	1.000	.000	.93	.19
				Leo	.833	.167	1.12	.37
				Chal	.833	.167	1.19	.40
		Turret Only	Front	M1	967	033	1.04	.31
				Leo	.900	.100	1.11	.37
				Chal	.700	.300	1.17	.38
			Flank	M1	.900	.100	99	20
				Leo	.900	.100	1.04	.21
				Chal	.700	.300	1.18	.36
	Foe	Whole Vehicle	Front	T62	833	167	89	18
				T64	.633	.367	1.23	.31
				T72	.667	.333	1.13	.28
			Flank	T62	1.000	.000	.95	18
				T64	1.000	.000	.99	.20
				T72	.900	.100	1.03	.35
		Turret Only	Front	T62	.933	.067	97	.22
				T64	.433	.567	1.42	.45
				T72	.833	.167	1.19	.46
			Flank	T62	.967	.033	.84	.17
				T64	.933	.067	.98	24
				T72	.967	.033	1.03	.32
100 ms	Friend	Whole Vehicle	Front	M1	1.000	.000	.89	.25
				Leo	.900	.100	90	32
				Chal	.800	.200	1.04	41
			Flank	M1	.967	.033	.80	.18
				Leo	.967	.033	90	.25
				Chal	.733	.267	1.00	.41
		Turret Only	Front	M1	.833	.167	.91	.23
				Leo	.767	233	.94	.19
				Chal	.633	.367	1.09	.44
			Flank	M1	.900	.100	.88	.19
				Leo	.900	100	.98	.25
				Chal	.400	.600	.92	32
	Foe	Whole Vehicle	Front	T62	.833	.167	.95	.25
				T64	.467	.533	1.00	.18
				T72	500	500	1.08	.42
			Flank	T62	.767	.233	.93	.25
				T64	.867	.133	.95	.35
				T72	.700	.300	.94	.28
		Turret Only	Front	T62	.933	.067	.81	.17
				T64	.633	.367	1.13	.38
				T72	.800	.200	97	.26
			Flank	T62	.933	.067	.73	.10
				T64	.967	.033	.87	.34
				T72	833	167	.81	.22

4.2 Between-Subject Analysis

Two analyses of variance (ANOVA) were computed for a between-subject analysis of proportion of Correct Responses and mean RT for Correct Responses. The analysis was collapsed across model in order to be able to perform the ANOVAs. With model included the ANOVAs could not be performed because of zero or negative degrees of freedom. The d's and β's were used to determine shifts in sensitivity and criterion between subjects. The evaluations of these shifts were used to gain insight into how the subjects were performing the recognition task.

4.2.1 Analysis of Correct Responses

The ANOVA for correct responses is shown in Table 9. The following main effects were significant:

Subject ($F_{9,320}$=2.40, p<.05)
Presentation Time ($F_{1,320}$=10.07, p<.01)
Type ($F_{1,320}$=5.03, p<.05)
Angle ($F_{1,320}$=17.87, p<.001)

Table 9
Between Subjects Analysis of Variance
for Percent Correct Recognitions

Source	DF	SS	MS	F	
Subject (S)	9	1.1469	0.1274	2.40	*
PresentTime(PT)	1	0.5347	0.5347	10.07	**
Type (T)	1	0.2670	0.2670	5.03	*
Component (C)	1	0.0082	0.0082	0.15	
Angle (A)	1	0.9487	0.9487	17.87	***
S*PT	9	0.3973	0.0441	0.83	
S*T	9	0.7368	0.0819	1.54	
S*C	9	0.4026	0.0447	0.84	
S*A	9	1.2676	0.1408	2.65	**
PT*T	1	0.0145	0.0145	0.27	
PT*C	1	0.0594	0.0594	1.12	
PT*A	1	0.0082	0.0082	0.15	
T*C	1	1.1330	1.1330	21.34	***
T*A	1	1.3356	1.3356	25.15	***
C*A	1	0.0035	0.0035	0.07	
S*PT*T	9	0.2139	0.0238	0.45	
S*PT*C	9	0.0937	0.0104	0.20	
S*PT*A	9	0.1529	0.0170	0.32	
S*T*C	9	1.9378	0.2153	4.05	***
S*T*A	9	1.5585	0.1732	3.26	***
S*C*A	9	0.7100	0.0789	1.49	
PT*T*C	1	0.3696	0.3696	6.96	**
PT*T*A	1	0.1116	0.1116	2.10	
T*C*A	1	0.0598	0.0598	1.13	
S*PT*T*C	9	0.8940	0.0993	1.87	
S*PT*T*A	9	0.3085	0.0343	0.65	
S*PT*C*A	9	0.1425	0.0158	0.30	
S*T*C*A	9	0.6241	0.0693	1.31	
PT*T*C*A	1	0.0010	0.0010	0.02	
S*PT*T*C*A	9	0.4786	0.0532	1.00	
ERROR	320	16.9915	0.0531		
TOTAL	479	32.9129			

Significance: * p≤.05; ** p<.01; *** p≤001

Of the main effects only component was not significant ($\underline{F}_{1,320}$=0.15, $\underline{p}$>.05). The most significant of the main effects was the angle the vehicle was presented at. Presentation time was more significant than either Subject or Type, indicating that a strong trend was observed between viewing the vehicle at 500 ms or 100 ms. There were also six significant interactions. Three of these interactions contained the main effect of subject, which will be addressed in a later section. These significant interactions were:

Subject*Angle ($\underline{F}_{9,320}$=2.65, $\underline{p}$<.01)
Type*Component ($\underline{F}_{1,320}$=21.34, $\underline{p}$<.001)
Type*Angle ($\underline{F}_{1,320}$=25.15, $\underline{p}$<.001)
Subject*Type*Component ($\underline{F}_{9,320}$=4.05, $\underline{p}$<.001)
Subject*Type*Angle ($\underline{F}_{9,320}$=3.26, $\underline{p}\leq$.001)
Present Time*Type*Component ($\underline{F}_{1,320}$=6.96,$\underline{p}$<.01)

The relationship of proportion correct between-subject for the 500 ms presentation can be seen in Figure 8. The overall proportion correct was slightly greater for friend vehicles than for foe vehicles (.88 versus .84). The figure also examines the main effects of component and angle. A closer look at component showed that, when viewing the whole vehicle, the observers were better able to correctly recognize friend vehicles than foe vehicles (.92 versus .84).

Observers recognized fewer friends (.845), but slightly more foes (.85), from turret only presentations. When viewing the vehicle from the front, observers did relatively well with friend vehicle (.90), but very poorly with the foe vehicles (.73). Foe recognition improved greatly when seen from the flank (.96), while the recognition of friends slightly declined (.86). In general, the best recognition for foes occurred viewing the vehicle as a turret only from the flank. The best combinations for friend recognition was to see the whole vehicle from the front.

The proportion correct at 100 ms presentation times is shown in Figure 9. In all cases except one, the proportion correctly recognized was less than for the same conditions in the 500 ms presentation. The recognition of foe vehicles, presented as turret only, remained constant at .85. Overall, friend vehicles were still recognized correctly more than foe vehicles (.82 versus .77). The best conditions for friend vehicles remained better than foe in the conditions of whole vehicles with frontal presentations. Foe vehicle recognition was better than friend vehicle recognition in the conditions of turret only and flank views. These are the same basic trends that were seen for the 500 ms presentations.

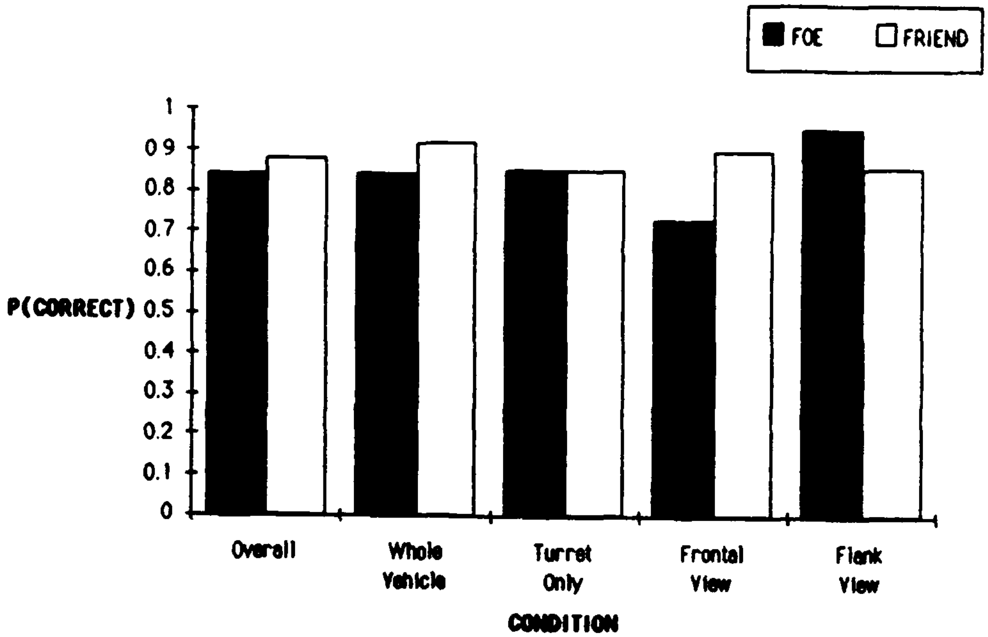


Figure 8
Friend Versus Foe Correct Recognitions (500 ms)

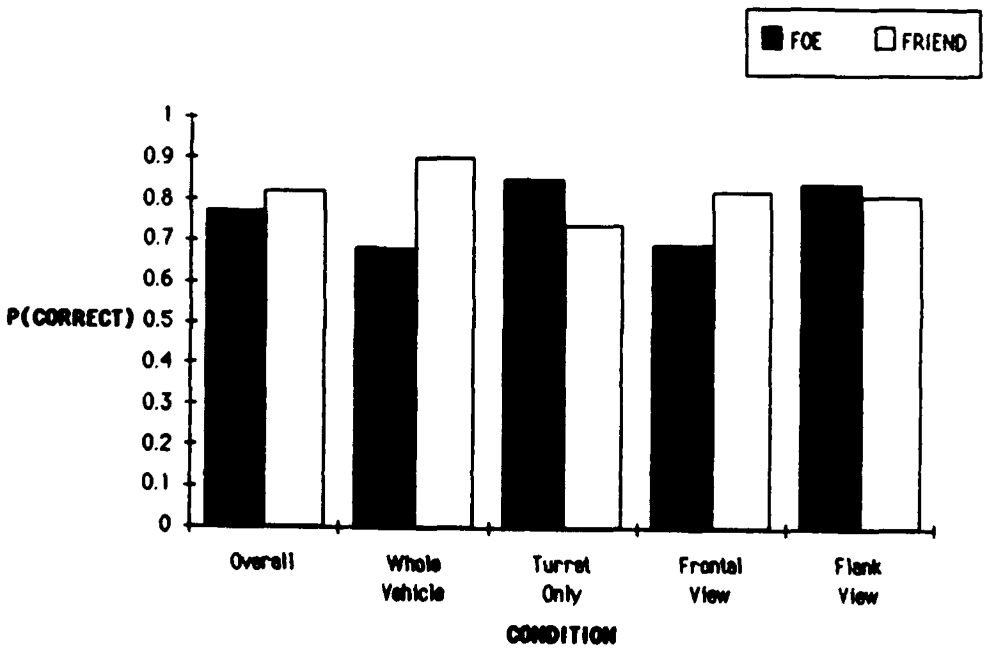


Figure 9
Friend Versus Foe Correct Recognitions (100 ms)

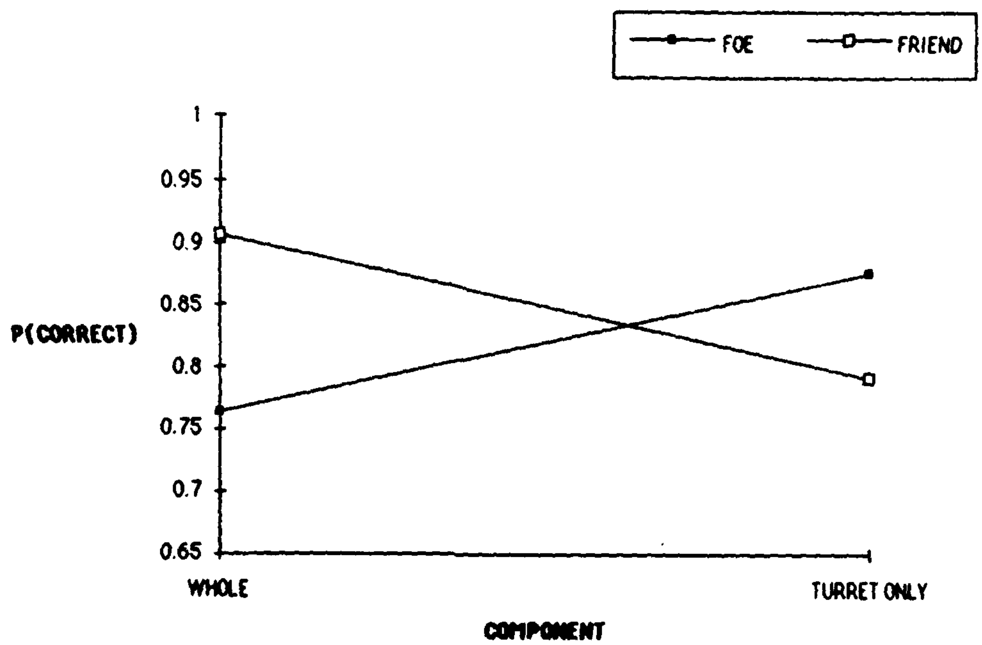
Three of the significant interactions from the ANOVA for proportion of Correct Responses did not include the main effect of subject. The trends that these interactions created are presented by the trend graphs shown in Figure 10. Figure 10a shows the trend that results from the significant interaction of Type*Component ($F_{1,320}$=21.34, p<.001). Friend vehicles were correctly recognized at a higher proportion than the foe vehicles when viewed as whole vehicles (.91 versus .76). As the component presented changed from a whole vehicle presentation to a turret only presentation the relationship changes. At the turret only presentations, foe vehicles were correctly recognized a higher proportion of the time than friend vehicles (.88 versus .79).

The trend of the significant interaction of Type*Angle ($F_{1,320}$=25.15, p<.001) is presented in Figure 10b. It shows a similar trend as seen in the previous interaction. The foe and friend vehicles were correctly recognized at different proportions given the different viewing angles. When viewed from the front, friend vehicles were recognized correctly better than foe vehicles were (.86 versus .70). This relationship is reversed as the view changed from frontal to flank views. At the flank presentations, foes are correctly recognized at a greater proportion than friends (.90 versus .84).

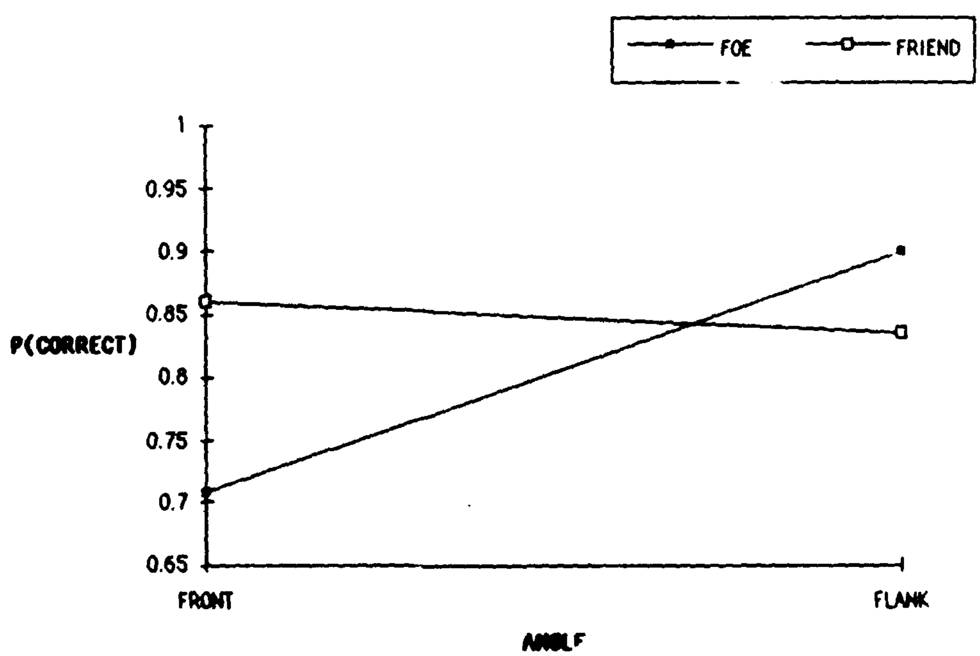
The only three way interaction that was significant was Presentation time*Type*Component ($\underline{F}_{1,320}$=6.96, $\underline{p}$<.01). The trends observed because of this interaction are shown in Figures 10c and 10d. As Figure 10c shows, at the 500 ms presentations, friend vehicles were correctly recognized at a greater proportion of the time than foe vehicles when presented as wholes (.92 versus .84). As the presentation at 500 ms changes from a whole to a flank view, the proportion of friend vehicles correctly recognized decreased from .92 to .845. The proportion of foe vehicles correctly recognized during the change from wholes to turrets only, slightly increased from .84 to .85. The same trend can be seen with the 100 ms presentations. When whole vehicles were presented, friend vehicles were correctly recognized at a higher proportion than foes vehicles (.89 versus .68). As the presentation changed from a whole vehicle to a turret only, friend vehicle correct recognitions dropped from a proportion of .89 to .74. During the same change, foe vehicle correct recognition proportions increased from .68 to .85.

These trends provide further evidence that there was a different strategy used by the subjects for viewing either a friend or a foe. For friend vehicles, the evidence supports the idea that the subjects could recognize whole vehicles from the front best. The friend vehicles were the most familiar to the subjects. This increased level of familiarity was a factor in the ability to recognize the friend vehicles when fewer cues were present. Foe vehicles were recognized best from the flank with turret only presentations. Since the foe vehicles were less familiar to the subjects, more cues were needed to recognize the vehicles. The flank view of the vehicle presented the most cues. The turret is the single component that contains the most cues.

The trend of how both the friend and foe vehicles were recognized was present at both the 500 ms and the 100 ms presentation times. The presence of the trend at both presentation times inidcates that different cognitive processing is occurring for each specific vehicle type at both times.

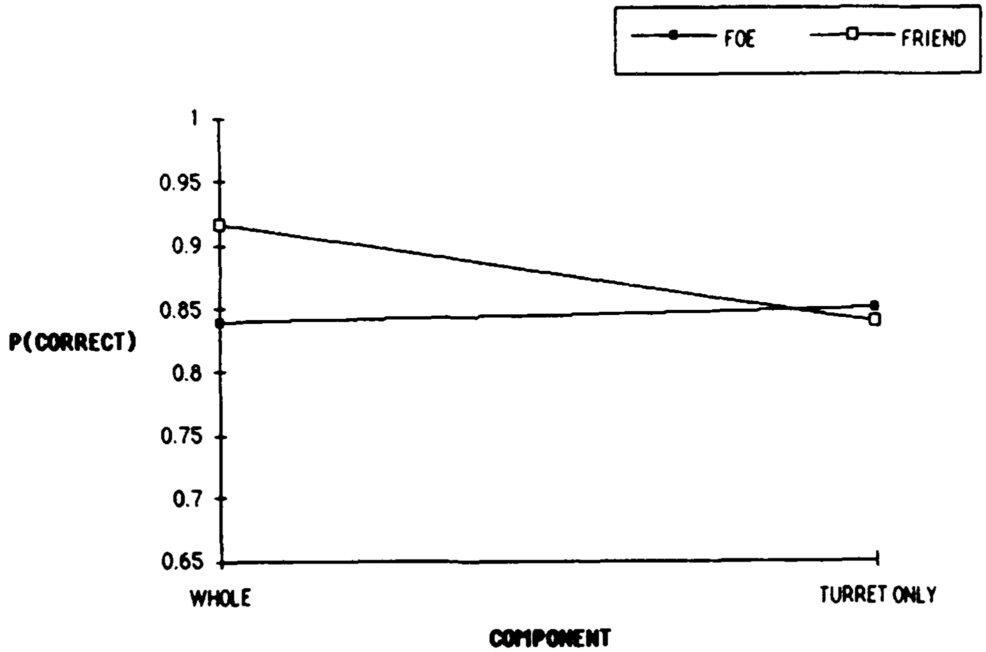


(a) Type*Component

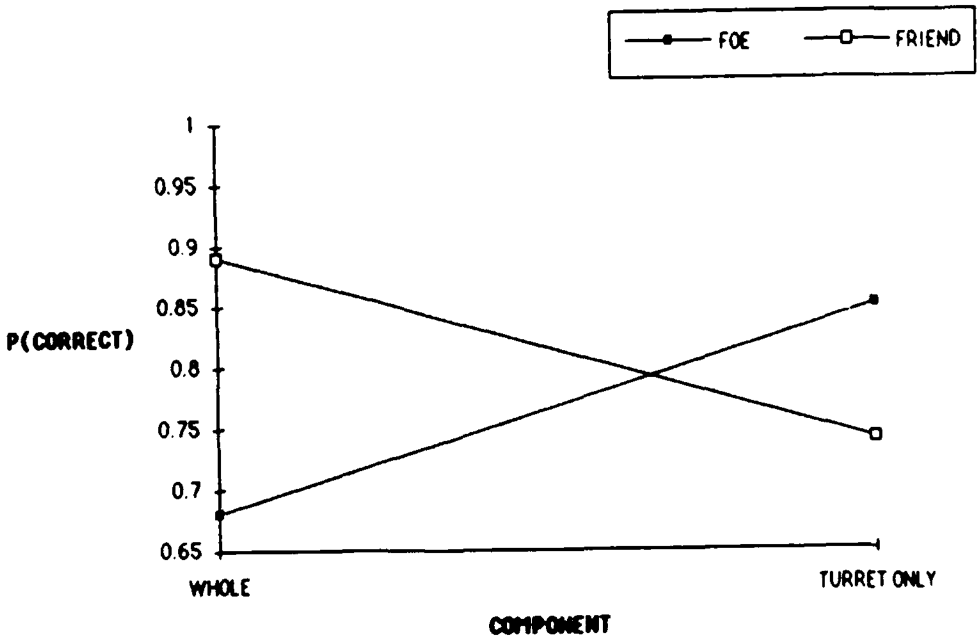


(b) Type*Angle

Figure 10
Trends from Significant Interactions
for Proportion Correct



(c) Presentation Time*Type*Component(500 ms)



(d) Presentation Time*Type*Component(100 ms)

Figure 10
Continued

4.2.2 Analysis of D-prime (d') and Beta (ß)

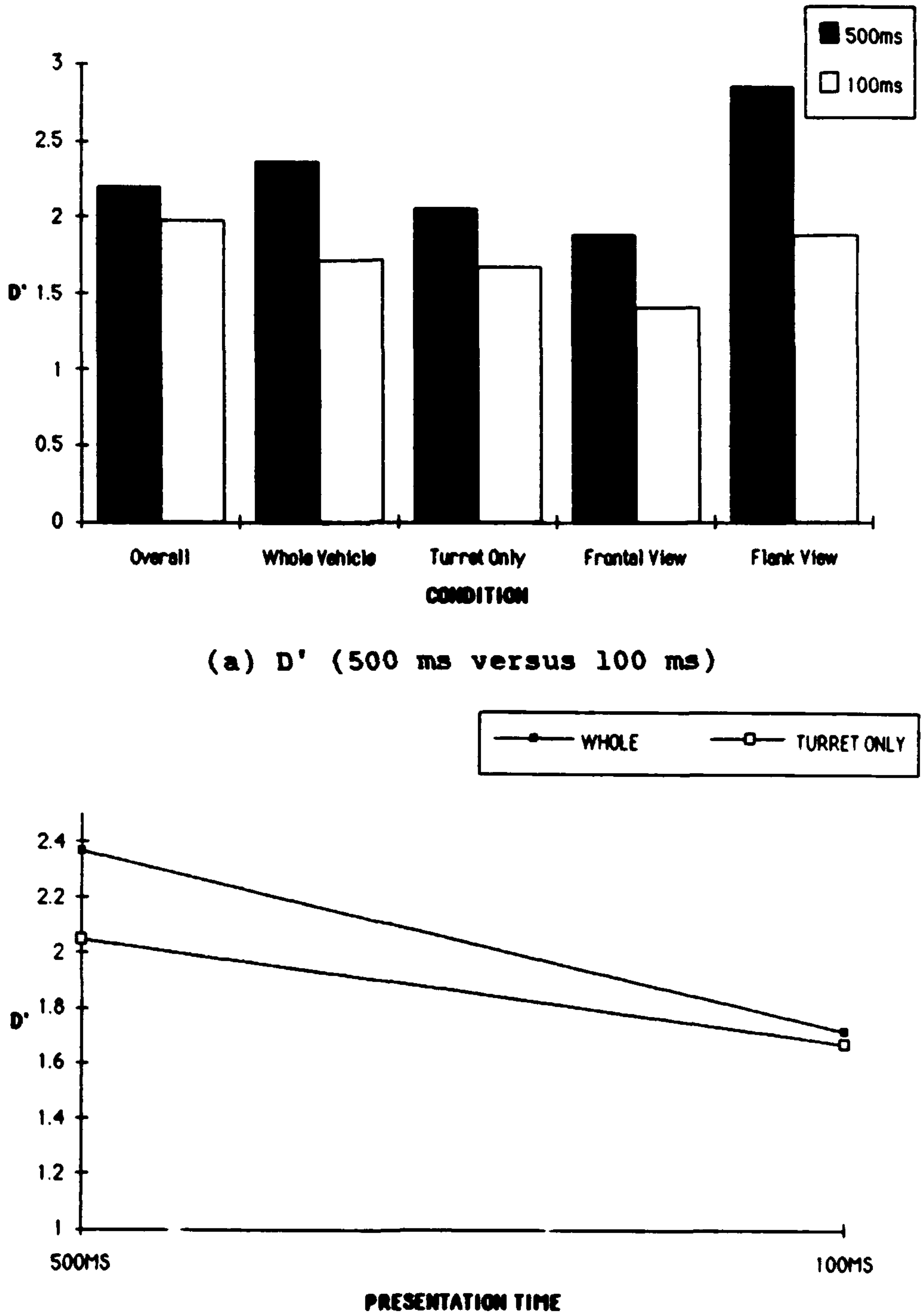
The d' values for the data shown in Figures 8 and 9 are compared to each other in Figure 11a. Across the board the d' values between-subject are less for the 100 ms presentations than for the 500 ms presentations. This reflects less of an absolute sensitivity overall for the 100 ms presentations. For the 500 ms presentation times, the d' values range from a high of 2.85 for flank views to a low of 1.89 for frontal views. For the 100 ms presentation time, the values ranged from a d' value of 1.89 for the flank views to a low of 1.41 for frontal views. At both presentation times, the d' for whole vehicle presentations was greater than for the turret only presentations. A comparison of the overall d' values between the presentation times shows a decrease from 2.20 for 500 ms to 1.98 for 100 ms. At 100 ms the observers overall had a more difficult time determining friend from foe. None of the d' values meet the rule-of-thumb guidelines as being a very difficult task (d'<1.5) or a very easy task (d'>3.5) (Craig, 1984).

The changes in the d' values can be seen more clearly in the trend graphs shown in Figures 11b and 11c. The change in the d' value, as the component presented changed, is shown in Figure 11b. At the

500 ms presentation time, the d' for whole vehicles was higher than for turrets only (2.37 versus 2.05). As the presentation time was decreased to 100 ms, both the d' values for whole vehicles and turrets only decreased. This indicated a decreased sensitivity for the observers at the 100 ms presentation time when they were looking at the different components. The whole vehicle presentations had d' values only slightly better than for the turret only presentation at 100 ms (1.72 versus 1.67).

The change in d' values with respect to the viewing angle also showed a similar trend between the presentation times. At the 500 ms presentation, the d' value for flank presentations was higher than for frontal presentations (2.85 versus 1.89). As the presentation time decreased to 100 ms, the d' values for both the frontal views and the flank views also decreased. The d' value for flank views remained higher than for the frontal views (1.89 versus 1.41).

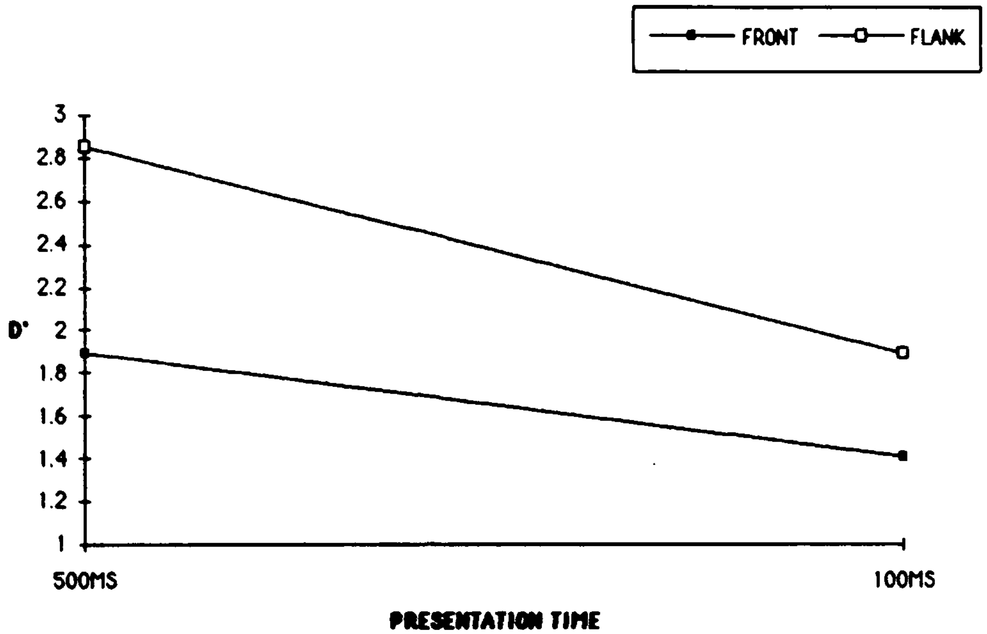
At both presentation times, the sensitivity was greater for the flank views than for the frontal views. This increased sensitivity can be directly attributed to the increased number of cues that are seen from the flank as opposed to the front of an armored vehicle.



(a) D' (500 ms versus 100 ms)

(b) D' Trend for Component

Figure 11
D-prime (d') Comparisons and Trends



(c) D' Trend for Angle

Figure 11
Continued

The computed β values for the data in Figures 8 and 9 are compared to each other in Figure 12a. The β values for the between-subject analysis shows no consistent trend between the 500 ms and 100 ms viewing times.

For the 500 ms presentation times, the β values ranged from a high of 1.89 for the frontal view of the vehicles to a low of .38 for the flank views. The overall β for the entire 500 ms presentation was 1.22. The β was higher than the overall for whole vehicle and frontal views and was lower than the overall for turret and flank views.

For the 100 ms presentation times, the β values ranged from a high of 1.95 for whole vehicle presentations to a low of .72 for turret only presentations. The overall β was 1.68. All the other β values were lower than the overall except for the high of 1.95.

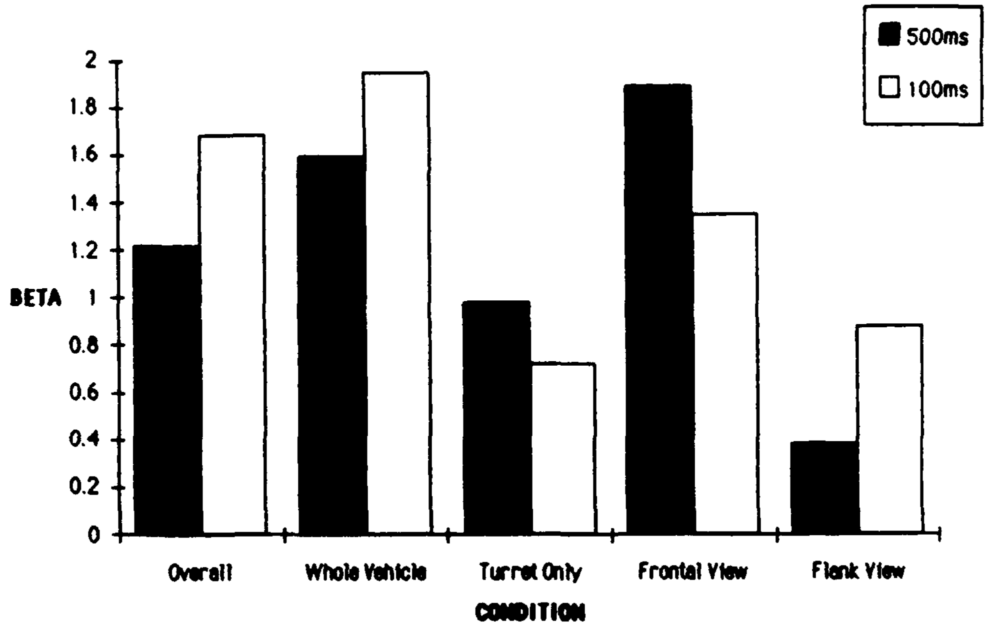
Comparing the β between the presentation times shows that the β gets smaller for the turret only and front view conditions as presentation time decreases. The β was greater in the overall, whole vehicle and flank conditions.

Using a β of 1 as the optimum, the βs for view (frontal or flank) move closer to the optimum as the presentation time decreases. The other βs move further away from the optimum as time decreases to include the overall. The basis for an optimal β of 1 is the evaluation that the costs and values of correct and incorrect recognition of friend and foe vehicles is the same. There is a cost of incorrectly identifying a friend which could result in fratricide. There is also a high cost of failing to recognize all the foes, the more foes on the battlefield not engaged, the more the danger of those vehicles attacking and destroying friend vehicles. The values of correct identification for both also result in the cancellation effect. With these two factors weighted equally, the optimal β becomes 1.

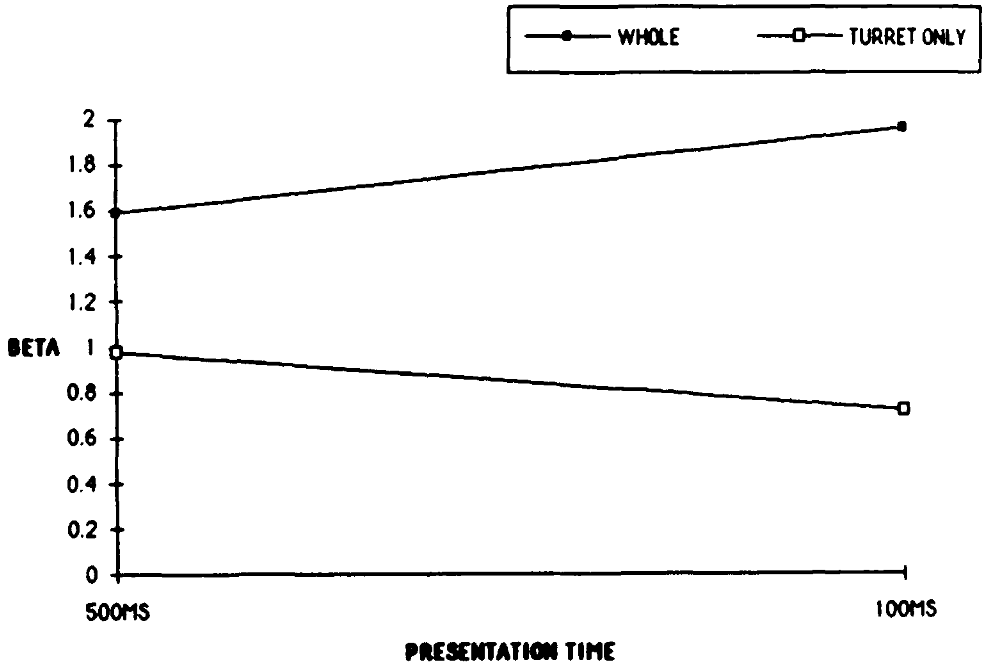
The changes in the β values between Component and Angle can be seen in Figures 12b and 12c. When the component presented was as whole vehicle, the criterion was higher than if a turret only was presented (Figure 12b). This was true at both the 500 ms and the 100 ms presentations. At 500 ms, the β for whole vehicles was 1.59, while the β for turret only was near the optimal of 1 at .98. As the presentation time decreased to 100 ms, the ß values for component moved further away from the optimal ß. The ß for whole vehicle presentations increased to 1.95 and the ß for turret only decreased to .72.

The trend for the ß values for the Viewing Angle showed an opposite trend as for Component (Figure 12c). At the 500 ms presentations, when a front view was shown the ß value was 1.89 compared to .38 for a flank view at the same presentation time. As the presentation time decreased to 100 ms, the ß values for both the frontal and flank presentation moved toward the optimal ß. The ß for front views changed to 1.35. The ß for flank views changed to .88.

The evidence from the trends indicated that the observers at 500 ms presentations had a better criterion for component than they did at 100 ms. At 500 ms presentations the crierion was closer to the optimal. For the viewing angles, the opposite was true, as the presentation time decreased, the ß improved. The observers criterion actually moved closer to the optimal as time presented decreased.

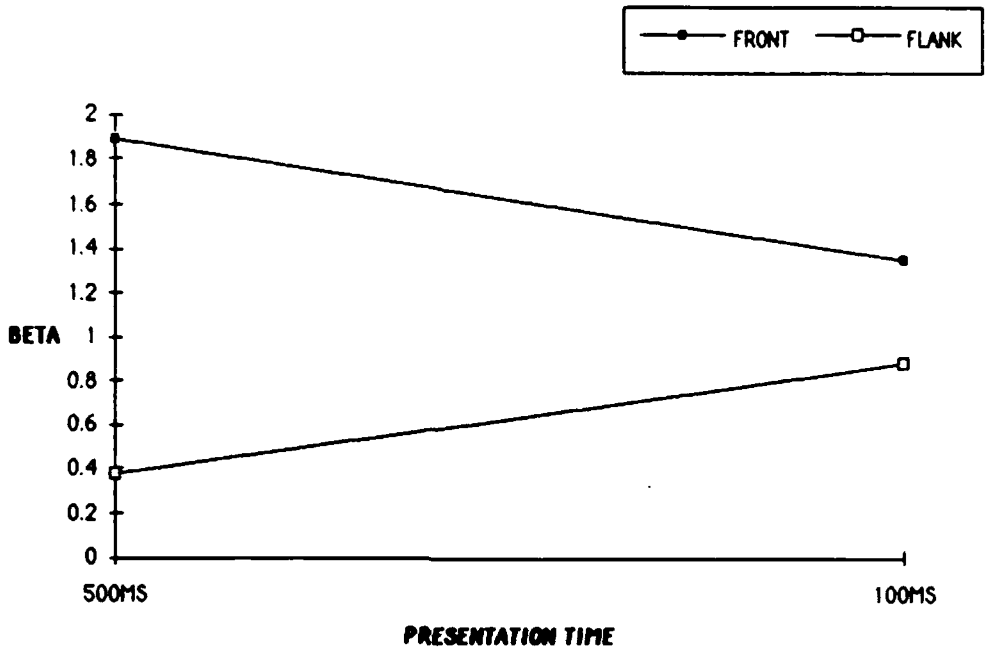


(a) Beta (500 ms versus 100 ms)



(b) Beta Trends for Component

Figure 12
Beta (β) Value Comparisons and Trends



(c) Beta Trends for Angle

Figure 12
Continued

4.2.3 Analysis of Mean Reaction Times

The ANOVA for the Mean Reaction Time of the correct responses is shown in Figure 10. The following main effects were significant:

Subject ($F_{9,320}$=14.49, p<.001)
Presentation Time ($F_{1,320}$=58.56, p<.001)
Angle ($F_{1,320}$=23.43, p<.001)

The main effects of Type ($F_{1,320}$=.35, p>.5) and Component ($F_{1,320}$=.09, p>.5) *were not* significant. Subject, Presentation Time, and Angle were all equally significant.

Eight interactions were significant:

Subject*Presentation Time ($F_{9,320}$=3.50, p<.001)
Subject*Type ($F_{9,320}$=2.77, p<.01)
Subject*Angle ($F_{9,320}$=3.68, p<.001)
Present Time*Component ($F_{1,320}$=4.65, p<.05)
Type*Component ($F_{1,320}$=3.87, p≤.05)
Type*Angle ($F_{1,320}$=14.81, p<.001)
Component*Angle ($F_{1,320}$=6.89, p<.01)
Subject*Type*Component ($F_{9,320}$=2.24, p<.05)

Table 10
Between Subjects Analysis of Variance
for Reaction Times

Source	DF	SS	MS	F	
Subject (S)	9	4.2600	.4733	14.49	***
Present Time (PT)	1	1.9130	1.9130	58.56	***
Type (T)	1	0.0113	0.0113	0.35	
Component (C)	1	0.0029	0.0029	0.09	
Angle (A)	1	0.7653	0.7653	23.43	***
S*PT	9	1.0303	0.1145	3.50	***
S*T	9	0.8141	0.0905	2.77	**
S*C	9	0.3924	0.0436	1.33	
S*A	9	1.0823	0.1203	3.68	***
PT*T	1	0.0010	0.0010	0.03	
PT*C	1	0.1520	0.1520	4.65	*
PT*A	1	0.0010	0.0010	0.03	
T*C	1	0.1264	0.1264	3.87	*
T*A	1	0.4840	0.4840	14.81	***
C*A	1	0.2252	0.2252	6.89	**
S*PT*T	9	0.2448	0.0272	0.83	
S*PT*C	9	0.1682	0.0187	0.57	
S*PT*A	9	0.0767	0.0085	0.26	
S*T*C	9	0.6582	0.0731	2.24	*
S*T*A	9	0.3103	0.0345	1.06	
S*C*A	9	0.2619	0.0291	0.89	
PT*T*C	1	0.0834	0.0834	2.55	
PT*T*A	1	0.1162	0.1162	3.56	
PT*C*A	1	0.0424	0.0424	1.30	
T*C*A	1	0.0272	0.0272	0.83	
S*PT*T*C	9	0.1299	0.0144	0.44	
S*PT*T*A	9	0.1797	0.0200	0.61	
S*PT*C*A	9	0.0949	0.0106	0.32	
S*T*C*A	9	0.3506	0.0390	1.19	
PT*T*C*A	1	0.0035	0.0035	0.11	
S*PT*T*C*A	9	0.2872	0.0319	0.98	
ERROR	320	10.4537	0.0327		
TOTAL	479	24.7499			

Significance: * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

A comparison of the correct response mean RTs for the 500 ms presentation can be seen in Figure 13. The mean RTs for the friend correct responses are larger than the foe mean RTs in all cases except the frontal view. For the friend vehicle correct recognitions, the quickest mean RT occurred for whole vehicle presentations (1.03 seconds). The slowest mean RT was for recognizing a friend vehicle was 1.12 seconds for the turret only presentations. The quickest mean RT for the foe vehicles was .97 seconds for flank presentations. The slowest for foe vehicles was 1.08 for the frontal presentations of the vehicles.

The mean RTs for friend and foe vehicle correct recognitions at 100 ms presentations are shown in Figure 14. In all cases the mean RTs were quicker for the 100 ms presentations than the 500 ms presentations. The quickest for the friend vehicle correct recognitions was .88 seconds for the whole vehicle presentations. This was the same condition as for the most rapid mean RT in the 500 ms presentations. The slowest mean RT was .95 seconds for the turret only presentations. Once again, this was the same as for the 500 ms presentation time.

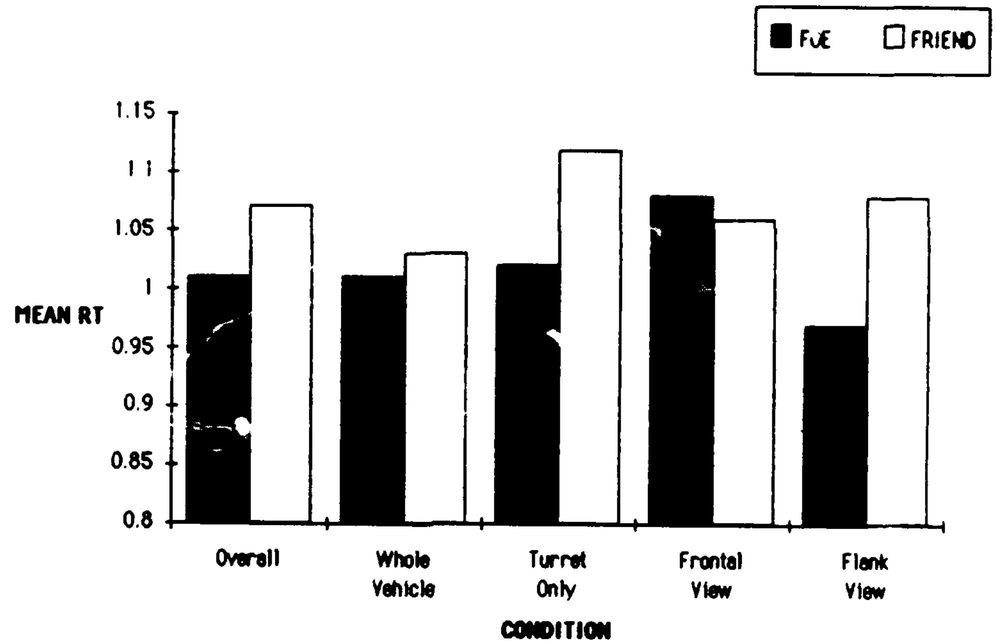


Figure 13
Friend Versus Foe Mean RTs (500 ms)

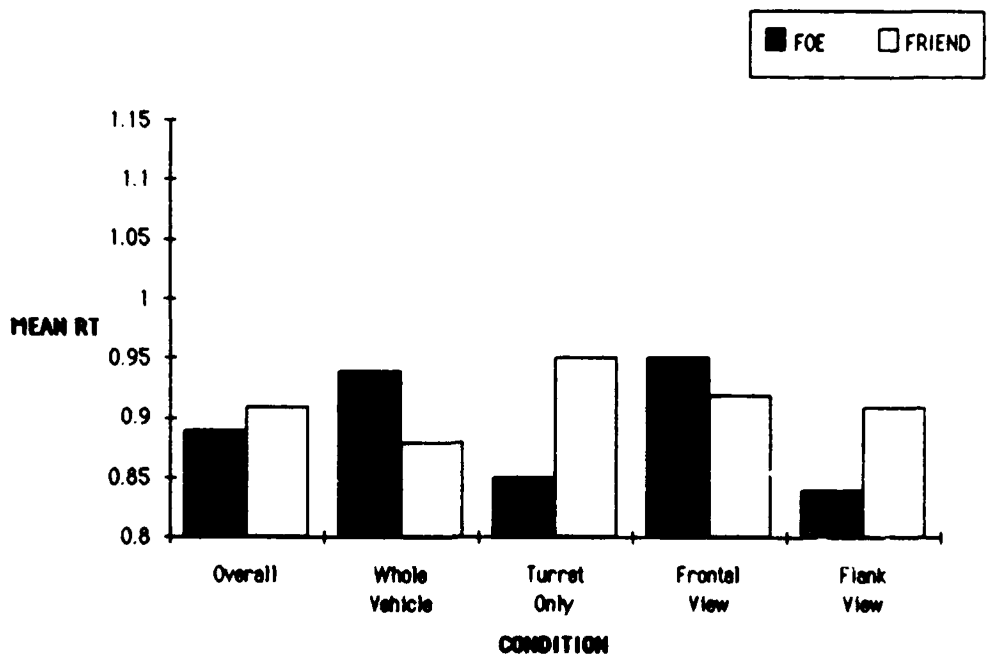


Figure 14
Friend Versus Foe Mean RTs (100 ms)

There were four significant interactions that did not involve subject for the ANOVA of the mean RTs of the correct responses. The trends that these interactions caused are presented in the trend graphs presented in Figure 15. The significant interaction of Presentation Time*Component ($\underline{F}_{1,320}$=4.65, $\underline{p}$<.05) is shown in Figure 15a. The mean RT for the correct responses were higher at 500 ms than at 100 ms. This was the case for both whole vehicle presentations and for turret only presentations. For the whole vehicle presentations, the mean RT was 1.02 seconds at 500 ms and .91 seconds at 100 ms. For the turret only presentations, mean RTs were 1.06 seconds for 500 ms and .90 seconds for 100 ms.

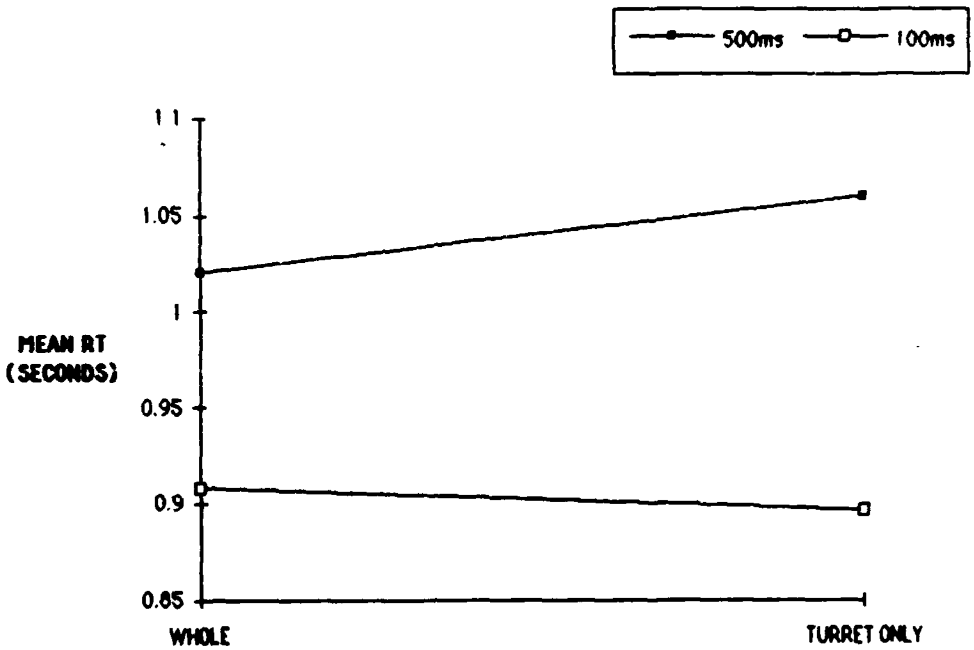
The trend on mean RTs that the interaction of Type*Component ($\underline{F}_{1,320}$=3.87, $\underline{p}\leq$.05) shows that foe vehicles required more time to correctly recognize when presented as a whole and friend vehicles required more time to correctly recognize when presented as a turret only (Figure 15b). When presented as a whole friend vehicles were recognized more rapidly than foe vehicles (.98 seconds versus .96 seconds). As the presentation changed to a turret only, the relationship was reversed and the difference in mean RTs was greater. Foe vehicles were correctly recognized more quickly than friend vehicles when presented as turret only presentations. the difference in mean RT was .93 seconds for foe vehicles and 1.04 seconds for friend vehicles.

The same trend that occurred for the previous interaction also occurred for the interaction of Type*Angle ($\underline{F}_{1,320}$=14.81, $\underline{p}$<.001) (Figure 15c). The foe vehicles took a slightly greater time to recognize than friend vehicles when they were presented at frontal views (1.02 seconds versus .99 seconds). As the view changed from a front to a flank, the relationship of the mean RTs also changed. When a flank view was shown, the foe vehicles were correctly recognized quicker at a mean RT of .91 seconds. Friend vehicles at the flank presentations were recognized at a mean RT of 1.00 seconds, a slight increase over the frontal presentations mean RT for the friend vehicles.

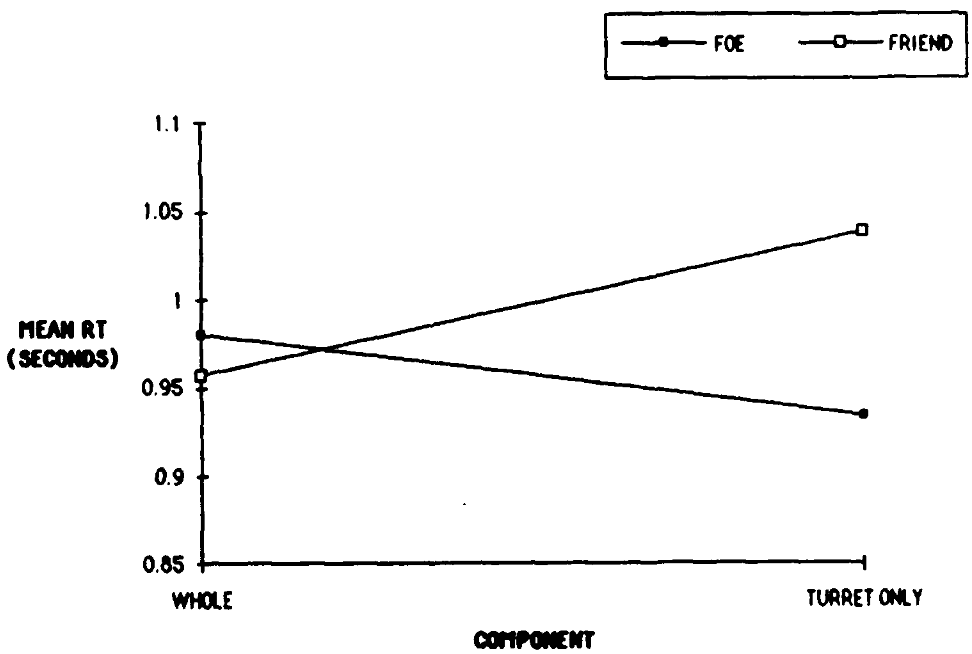
The significant interaction of Component*Angle ($\underline{F}_{1,320}$=6.89, $\underline{p}$<.01) showed that turret only views from the front took the longest time to recognize correctly and turret views from the flank took the least (Figure 15d). The difference in the mean RT for whole vehicles between front and flank views was very small, .98 and

.96 respectively. The difference for the turret only presentations showed a much greater range, from 1.03 seconds for frontal turrets to .94 seconds for flank turrets.

The trends from the mean RT interactions provide evidence that the decisions made by the subjects followed different strategies depending on the presentation. Trends indicate that at the lower presentation time, the decision was being made more quickly by the subject. Friend vehicles were recognized faster when presented as wholes from the front. The foe vehicles were recognized more quickly when the presentation was a turret only from the flank. In general, turrets regardless of whether they were friend or foe were recognized better when seen from the flank. Whole vehicle presentations had about the same mean RT whether the viewing angle was frontal or flank. These results continue to provide evidence that the subjects were looking at the vehicles in different ways. The mean RT values indicate that each of the vehicle types were being processed cognitively in different ways.

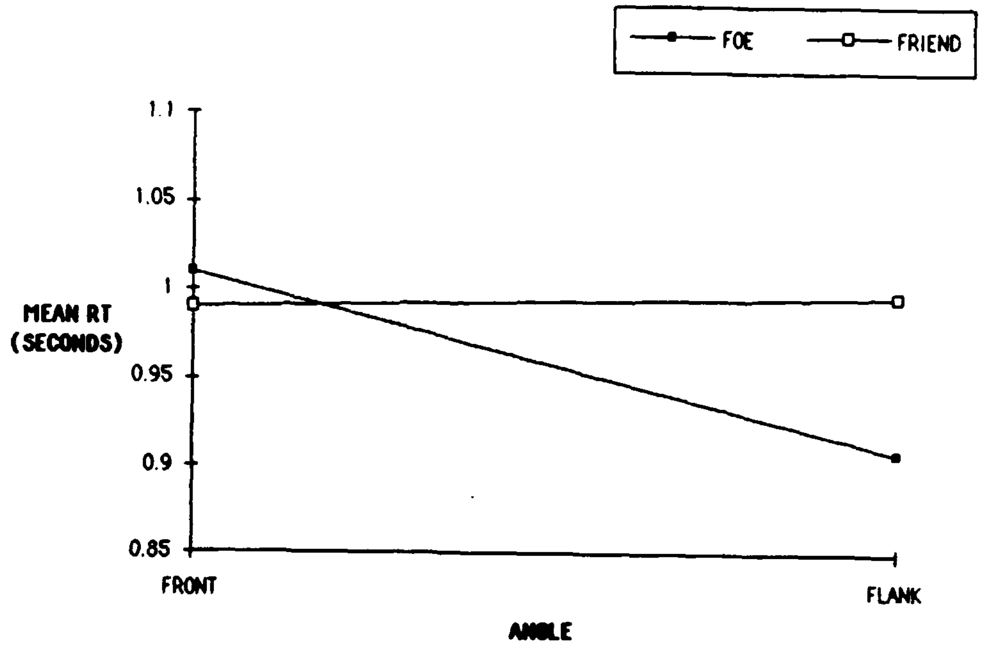


(a) Presentation Time*Component

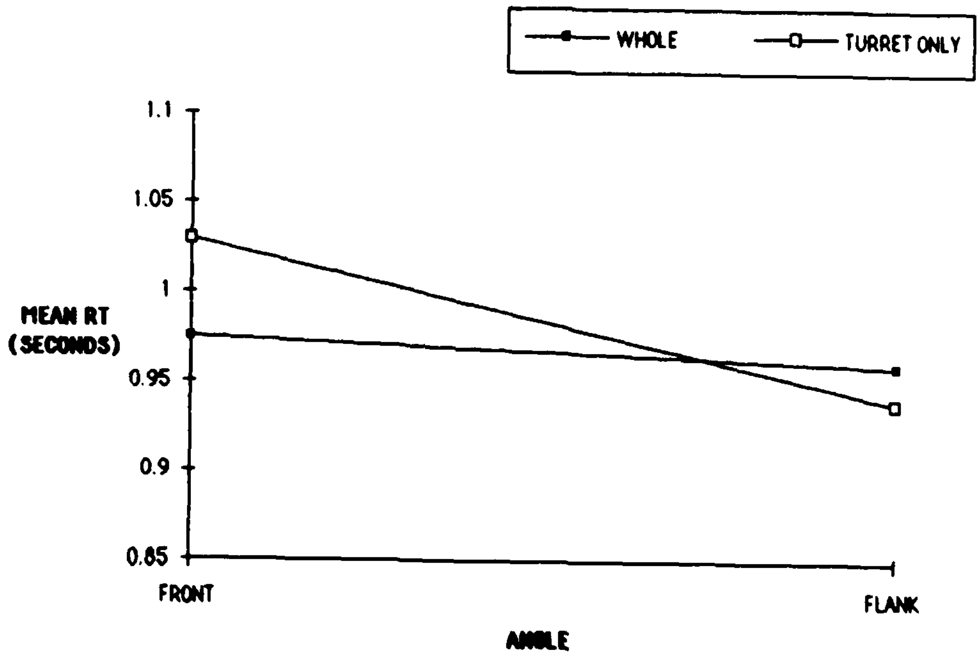


(b) Type*Component

Figure 15
Trends from Significant Interactions
for Mean RT



(c) Type*Angle



(d) Component*Angle

Figure 15
Continued

4.3 Individual Differences

As in any study using human beings there is a clear difference in recognition performance between the subjects. While each subject in the study was a company grade (Captain) in the U.S. Army with the same relative experience in years, their backgrounds within the Army and their job experience did reflect some individual differences. Three of the 10 subjects were members of the Combat Arms branches within the Army. The Combat Arms are those branches whose members are trained to conduct combat operations against the enemy. Subjects 6, 7, and 8 were members of the Combat Arms and their experience was primarily in these types of units. Subjects 6 and 8 were members of the Armor branch with extensive experience in and commanding tank equipped units in both the U.S. and Germany. Subject 7 was an Air Defense officer with extensive experience and training in aircraft identification. The remaining subjects were from the Combat Support branches and had much less experience in tactical units. In these support units, their exposure to armored vehicles would be less than that of a member of one of the Combat Arms branches. Only Subject 1 was a participant in operation Desert Storm as an Engineer officer.

4.4 Within-Subject Analysis

As shown in Tables 9 and 10, the main effect of Subject was significant for both Proportion Correct ($F_{9,320}$=2.40, p<.05) and mean RT ($F_{9,320}$=14.49, p<.001). As previously stated, the main effect of subject also influenced several significant interactions in both of the ANOVAs.

4.4.1 Within-Subject Analysis of Correct Responses

The relationship of the overall proportion correct for the presentation times of 500 ms and 100 ms can be seen in Figures 16 and 17, respectively. The data is broken down by subject to interpret the individual subject performance at the two presentation times.

At a presentation time of 500 ms, five of the subjects were able to correctly recognize friend vehicles better than foe vehicles (Figure 16). Three recognized the foe vehicles better than friend vehicles. The remaining two subjects recognized both types of vehicles correctly at the same level of performance. The best performance levels were for Subjects 7 and 8, recognizing friend vehicles correctly at a proportion of .95. The poorest recognition performance for both foe and friend correct recognitions at 500 ms was by Subject 1. The best overall, recognizing foes at a proportion of .944 and friends at a proportion of .945, was by Subject 8.

As the presentation time decreased to 100 ms, fewer correct recognitions were performed by most of the subjects (Figure 17). Eight of the subjects correctly recognized friends at a lower proportion of the time. The best performance for friend vehicle recognition came from Subject 7 who correctly recognized friends correctly at a proportion of .97. The worst performance was Subject 5 at a proportion correctly recognized of .67. Eight of the subjects correctly recognized foes at a lower proportion. The best foe recognition was from Subject 8 at a proportion of .86. The worst foe recognition was from Subject 1 at .61. For the friend vehicles, this lower proportion correctly recognized translated into more False Alarms and therefore more potential friendly fire incidents. The lower proportion of foes correctly recognized at 100 ms translated into more foe vehicles not being engaged and therefore remaining a threat on the battlefield. The increased number of threat vehicles on the battlefield is as serious a problem as engaging friend vehicles. The greater the number of enemy vehicles, the greater the chances of friend being killed by them.

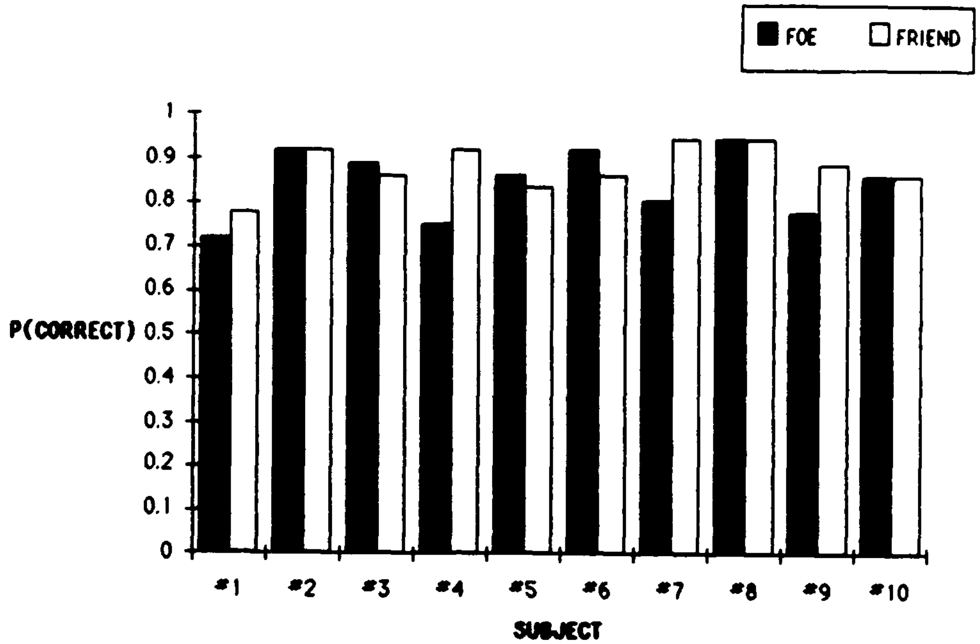


Figure 16
Friend Versus Foe Correct Recognitions
Within-Subject (500 ms)

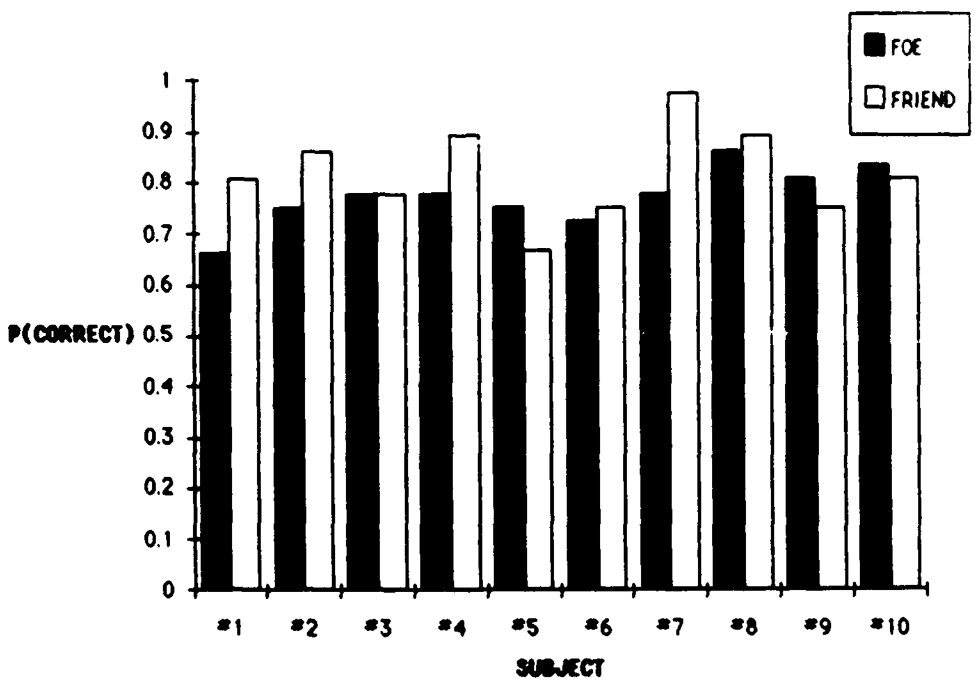


Figure 17
Friend Versus Foe Correct Recognitions
Within-Subject (100 ms)

4.4.2 Within-Subject D-prime (d') and Beta(ß)

The analysis of the d' and ß for the subjects can provide insight into why the changes in correct recognitions were occurring. A comparison of the d' values between the 500 ms and 100 ms presentation time is shown in Figure 18. Except for Subject 7, there was a decrease in the d' values as presentation time was reduced from 500 ms to 100 ms. The range of the d' values for the 500 ms presentations went from a low of 1.35 for Subject 1 to a high of 3.19 for Subject 8. The sensitivity for Subject 1 was one of the reasons his correct recognition proportions for the 500 ms presentation was the worst of the subjects. The high of 3.19 for Subject 8 reflects that he correctly recognized both friends and foes at the highest proportions. The lower d' values reveals why in general the correct recognitions were reduced for the 100 ms presentations. The exception was Subject 7 whose d' went from 2.46 at 500 ms to 2.69 at 100 ms. This reflects his better recognition of friend vehicles at 100 ms as compared to 500 ms.

Subject's ß values are shown in Figure 19. The ß values indicate that the subjects may have responded differently with the reduction in viewing time. Six of the subjects (1, 2, 3, 6, 7, & 8) adopted a more

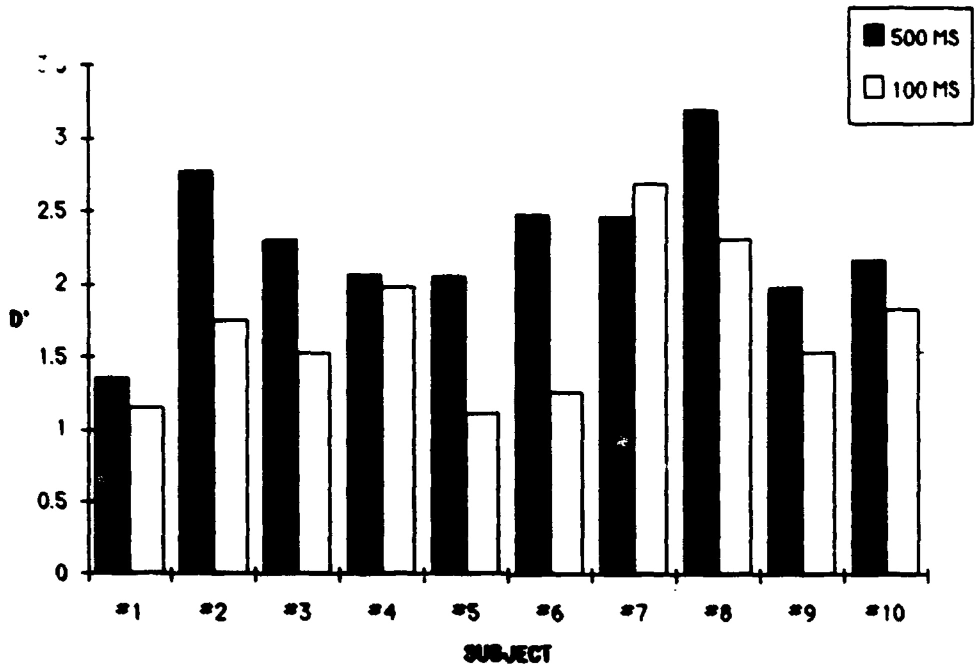


Figure 18
Within-Subject D-prime (d') Values
(500 ms versus 100 ms)

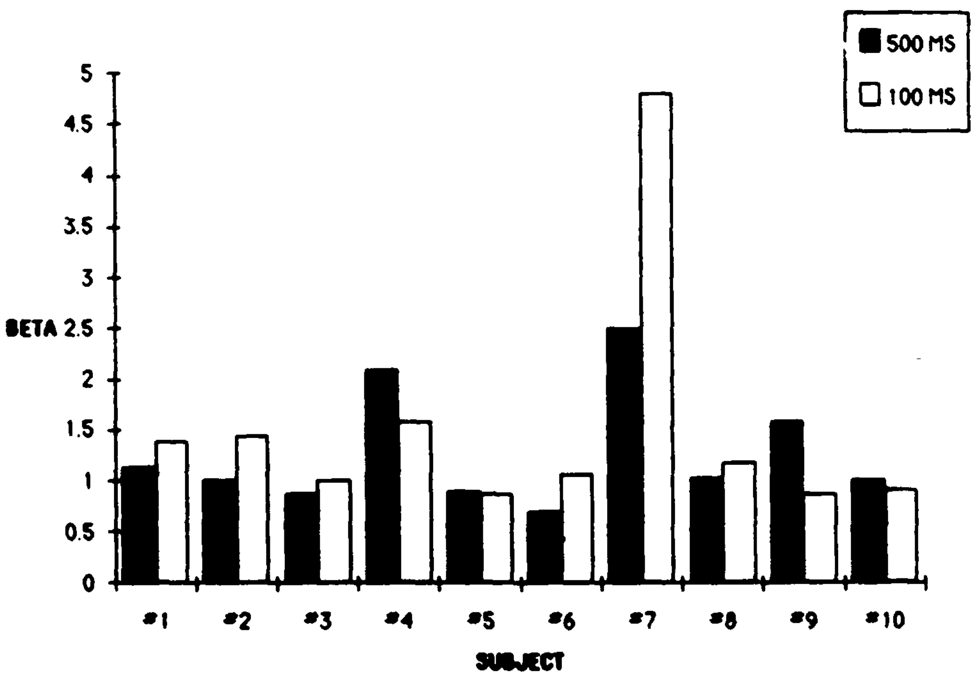


Figure 19
Within-Subject Beta (β) Values
(500 ms versus 100 ms)

conservative criterion with the reduced presentation time. Being more conservative is the result of decreased hit rate for foe vehicles and a decrease in the number of false alarms for friend vehicles. The remaining four subjects became more liberal in their criterion with the reduced presentation time. The more liberal the criterion, the more the subject increases his hits and false alarms. At the 500 ms presentation time, Subjects 2, 8, and 10 had βs that were at or near the optimal β of 1.00. At the 100 ms presentation, only Subject 3 had a β of 1.00. Between the presentation times, Subjects 1, 2, 7, 8, and 10 moved further away from the Optimal β. Subjects 3, 4, 5, 6, and 9 moved toward the Optimal β at the reduced viewing time.

4.4.3 Within-Subject Analysis of Component and Angle

Both Component and Angle were significant to some extent either as a main effect or as part of an interaction with respect to Correct Recognitions. It is important to see how the individual subjects performed the recognition task when these factors were taken into account.

4.4.3.1 Analysis of Component

The analysis of how the main effect of component effect the subject performance can be seen in Figures 20 to 23. Foe recognition was better for turret only and flank views, while friend vehicle recognition was better for the whole vehicle presentations and frontal views. To more fully understand this it is important to evaluate how the individual subjects performed.

Figures 20 and 21 show how each subject performed the recognition task when presented whole vehicles at the different presentation times. The correct recognition of friend vehicles was better than for foe vehicles for most of the subjects regardless of the time. At a presentation time of 500 ms, 7 of 10 of the subjects recognized friends correctly better than they did foes. At a presentation time of 100 ms, that improved to 9 of 10 of the subjects. Five of the subjects recognized a smaller proportion of the friend vehicles correctly at the shorter presentation time. Two subjects did the same and three actually improved their proportion correct going to the shorter presentation time. For foe vehicles, six of the subjects recognized a smaller proportion correctly. The remaining four subjects did the same at the shorter presentation time.

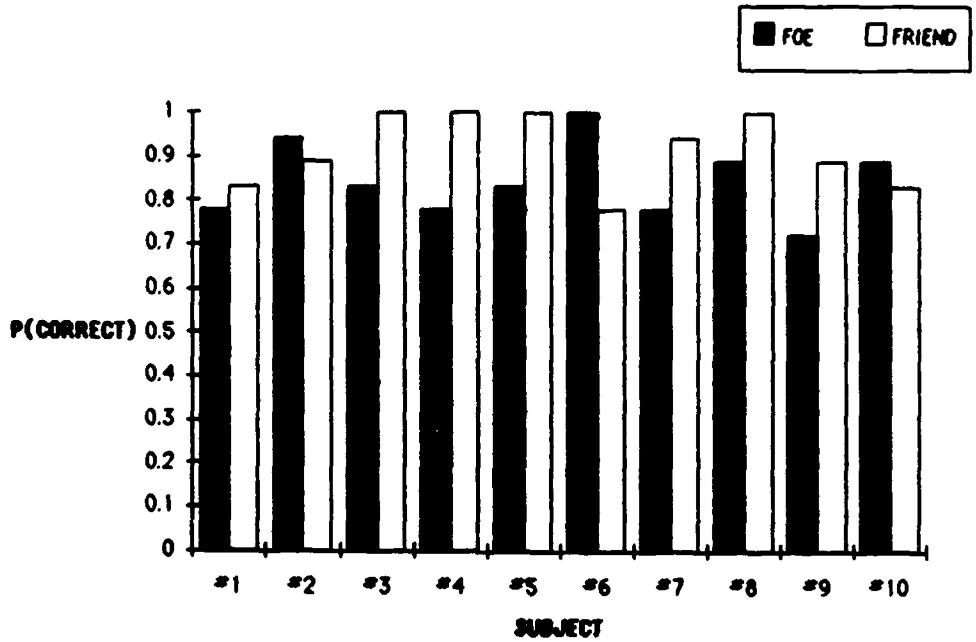


Figure 20
Within-Subject Correct Recognitions for
Whole Vehicles (500 ms)

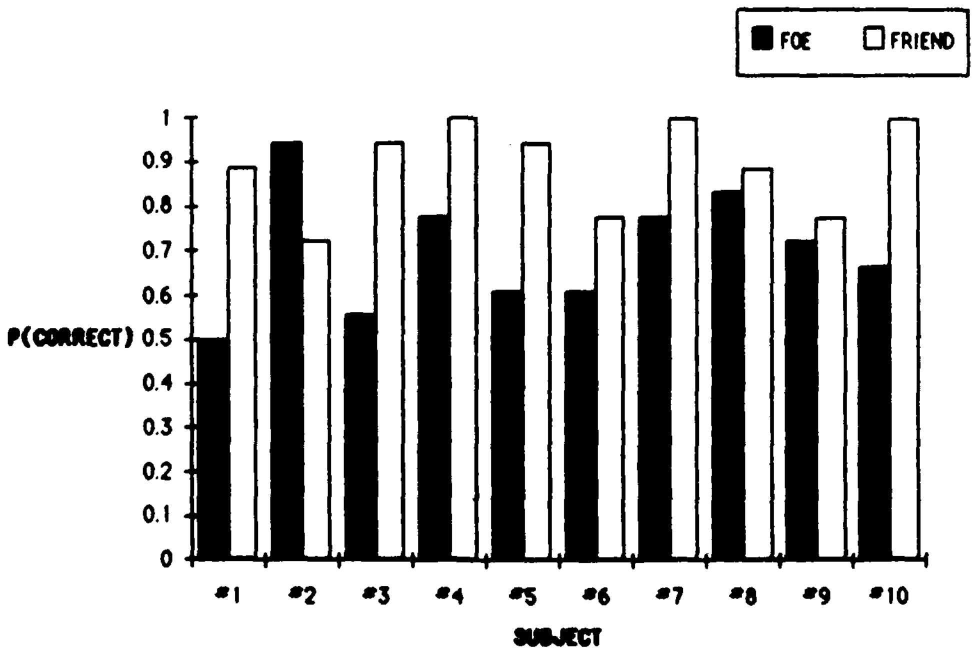


Figure 21
Within-Subject Correct Recognitions for
Whole Vehicles (100 ms)

Figures 22 and 23 show how the subjects performed the recognition task when presented turrets only. At a 500 ms presentation, friend vehicles were recognized correctly at a higher proportion than foe vehicles by 6 of 10 subjects. Three of the subjects recognized the foe vehicles correctly a higher the proportion of the time. The remaining subject did the same for both. As the presentation time was reduced to 100 ms, foe vehicles were recognized correctly a higher proportion as compared to friend vehicles by 7 of the 10 subjects. Six of these subjects actually improved their recognition performance. The friend vehicle correct recognitions were less for six of the subjects. Subjects 1 and 8 recognized the friend vehicles the same at both presentation times. Subject 2 improved his performance at the shorter presentation time.

The general trend for the subjects is that they can recognize foe vehicles better when seeing the turret only at the quicker presentation time.
The longer the presentation time, the better friend vehicles are recognized. This indicates that the subjects are possibly looking at fewer components on the foe vehicles. It also indicates that for friend vehicles the subjects are accessing a more complete mental representation.

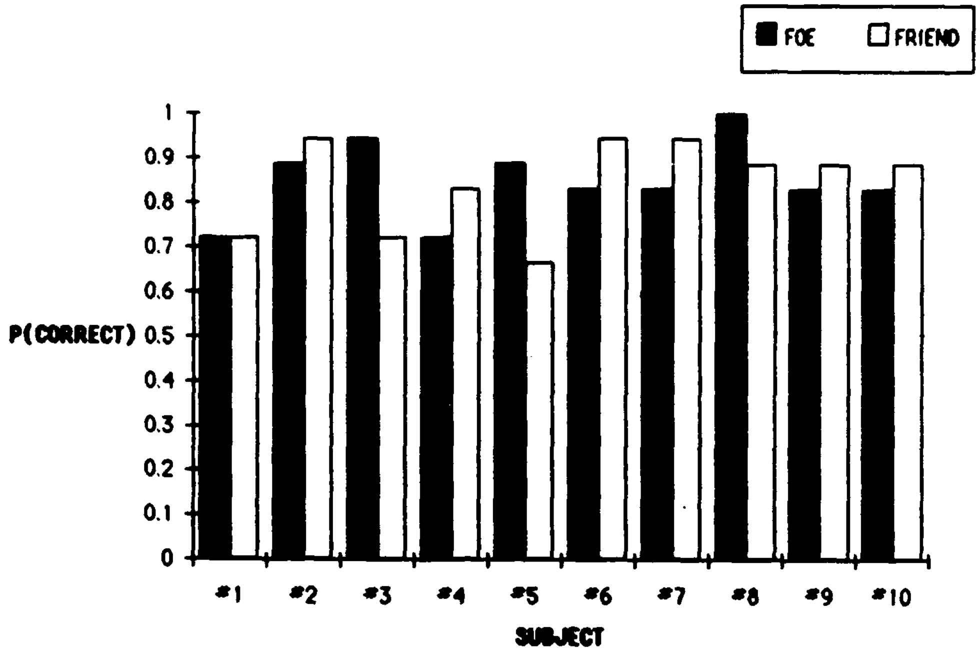


Figure 22
Within-Subject Correct Recognitions for Turrets Only (500 ms)

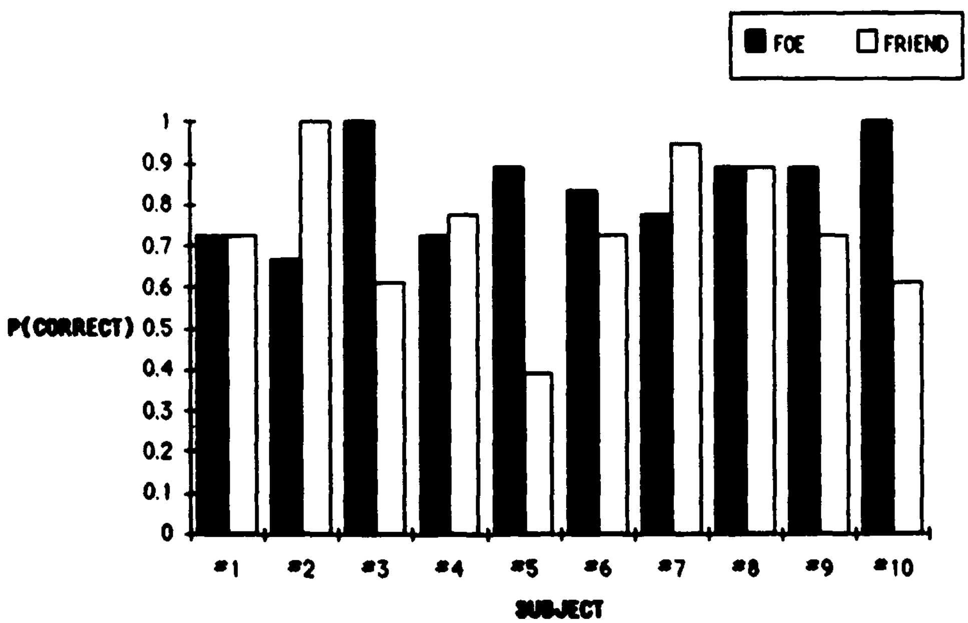


Figure 23
Within-Subject Correct Recognitions for Turrets Only (100 ms)

4.4.3.2 Analysis of Angle

The analysis of how the main effect of angle effected subject performance can be seen in Figures 24 to 27. When viewing the front, it was easier to recognize friends than foes. The flank view was better for recognizing foes. Figures 24 and 25 show how the subjects performed the recognition task when presented with a frontal view. At 500 ms, eight of the subjects recognized the friend vehicles correctly at a higher proportion than they did the foe vehicles. Only Subject 8 recognized the foe vehicles better. The trend remained the same as the presentation time was reduced to 100 ms with seven of the subjects continuing to recognize the friends better. Subjects 2, 5, 8, and 9 had a reduced proportion of friend vehicles correctly identified at 100 ms. The remaining subjects did as well at 100 ms, except for Subject 7 who actually improved. Seven of the subjects recognized foe vehicles worse at the 100 ms presentations. The remaining subjects improved correct recognitions, but did not do as well as they did for friend correct recognitions.

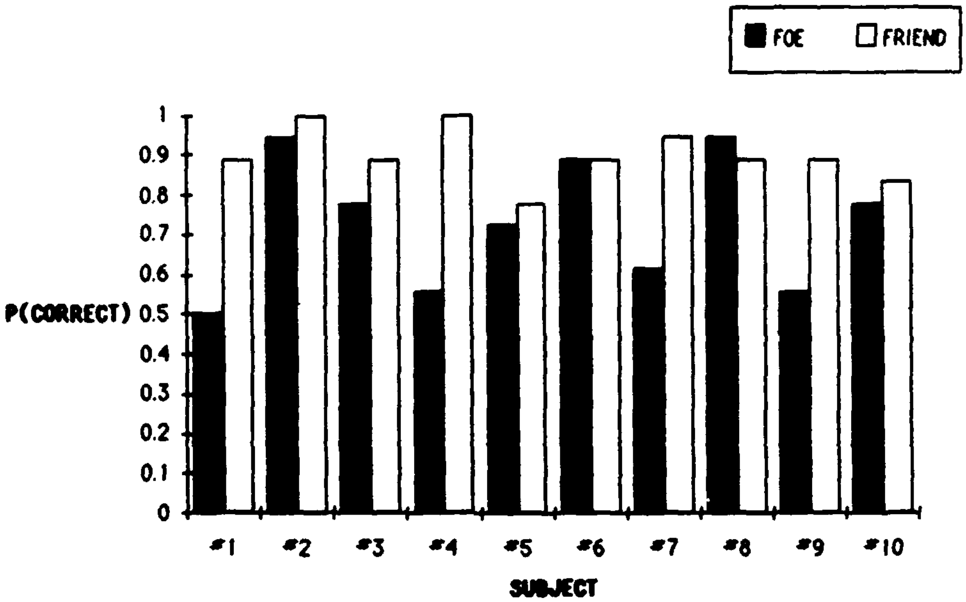


Figure 24
Within-Subject Correct Recognitions for
Frontal Views (500 ms)

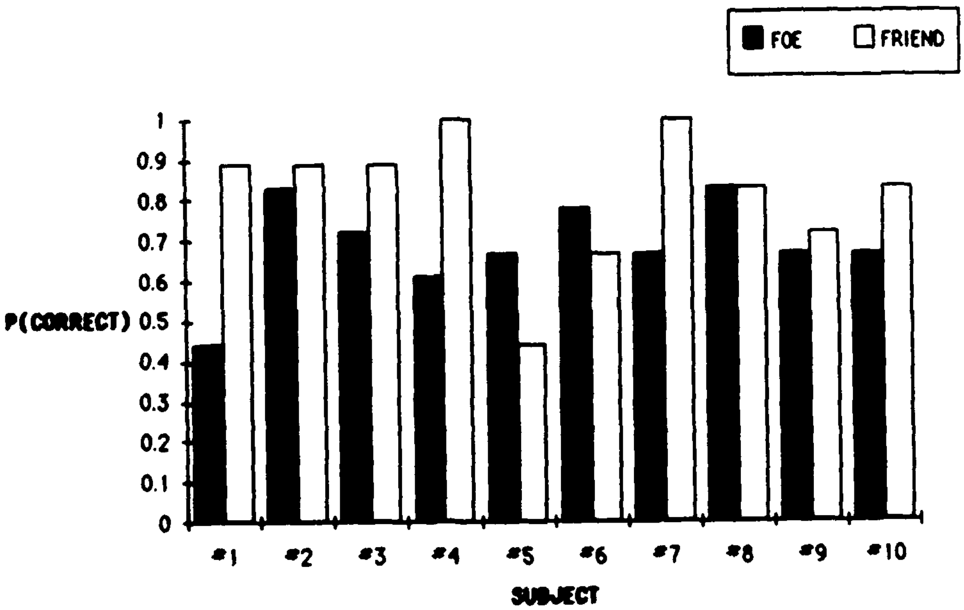


Figure 25
Within-Subject Correct Recognitions for
Frontal Views (100 ms)

The recognition performance of the subjects for flank presentations are shown in Figures 26 and 27. The trend previously discussed was that for flank presentations, the proportion of foes correctly identified was higher than for friends. As Figure 26 shows, at 500 ms presentations, nine of the subjects had higher proportions of foe vehicles correctly recognized than they did friend vehicles. Subject 8 was the only exception to the trend. As the presentation time reduced to 100 ms (Figure 27), five of the subjects continued to report better correct recognition proportions for foe vehicles. Subjects 2, 5, 6, 7, and 8 had greater accuracy with the friend vehicles at the shorter presentation time. Overall the subjects recognized the foe vehicles better from the flank than they did the friend vehicles.

4.4.4 Within-Subject Analysis of Mean Reaction Time

The ANOVA performed for mean Reaction Time (RT) (Table 10) showed that Subject was highly significant ($F_{9,320}$=14.49, p<.001). The between-subject trends suggested that foe vehicle flank views were recognized correctly quicker than the friend vehicles. Friend vehicles were recognized quicker at frontal presentations than the foe vehicles. In general, mean

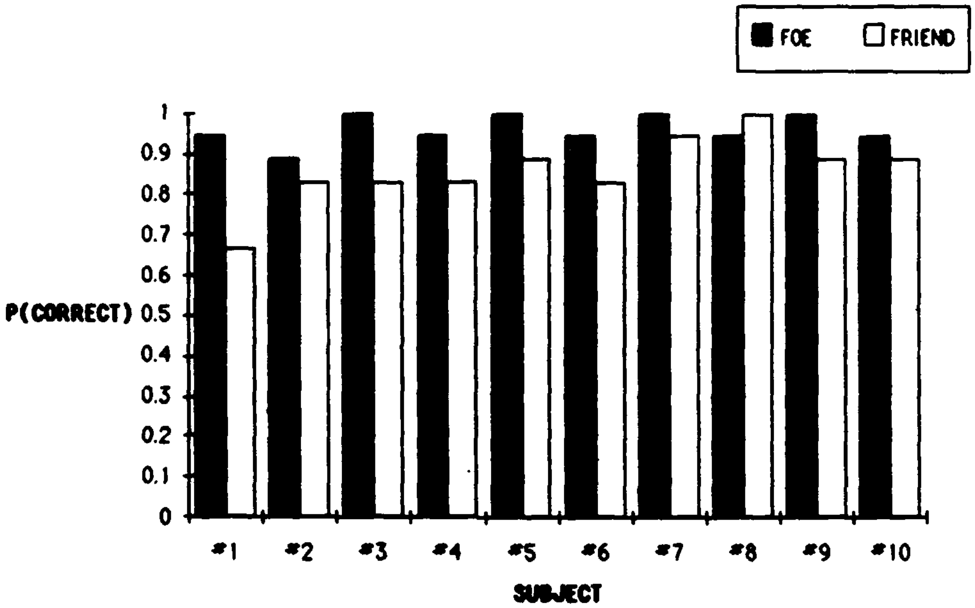


Figure 26
Within-Subject Correct Recognitions for
Flank Views (500 ms)

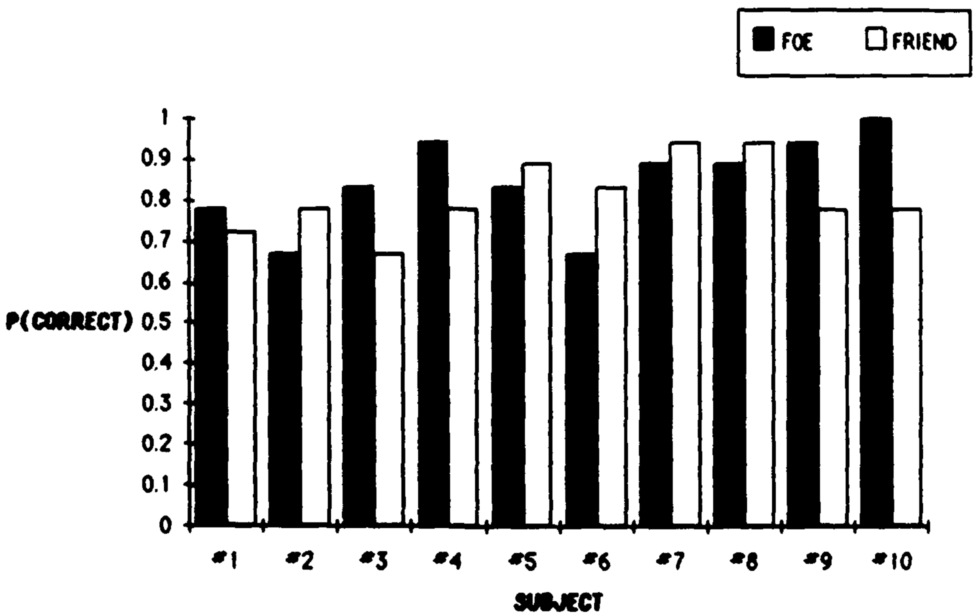


Figure 27
Within-Subject Correct Recognitions for
Flank Views (100 ms)

RTs were quicker at the 100 ms presentations.

The within-subject analysis of overall mean RTs is shown in Figures 28 and 29. Figure 28 shows the correct recognition performance of the subjects at the 500 ms presentations. At his presentation time, 7 of 10 subjects took longer to correctly identify friend vehicles. Subject 5 had the quickest mean RT for recognizing both foes and friends, .91 seconds and .97 seconds respectively. The longest recognition time for foe vehicles was by Subject 2 at 1.08 seconds. Subject 6 had the longest for friend vehicles at 1.33 seconds.

The subject's performance, at the 100 ms presentation time, is shown in Figure 29. At this presentation time, 6 of 10 subjects had longer mean RTs for recognizing friend vehicles. In all cases, the subjects reduced their mean RTs for both friend and foe vehicles. The range for foe vehicles was from a low of .73 seconds by Subject 1, to a high of 1.06 seconds by Subject 6. The range for friend vehicles was from .71 seconds for Subject 1, to a high of 1.04 seconds by Subject 6. This indicates a consistency in the performance of the subjects.

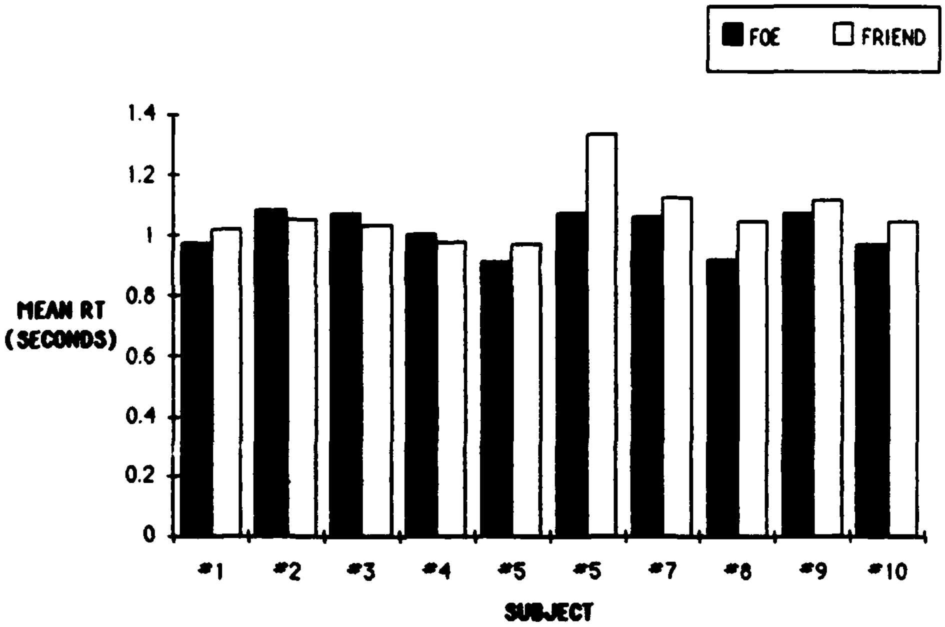


Figure 28
Within-Subject Mean RTs
Overall (500 ms)

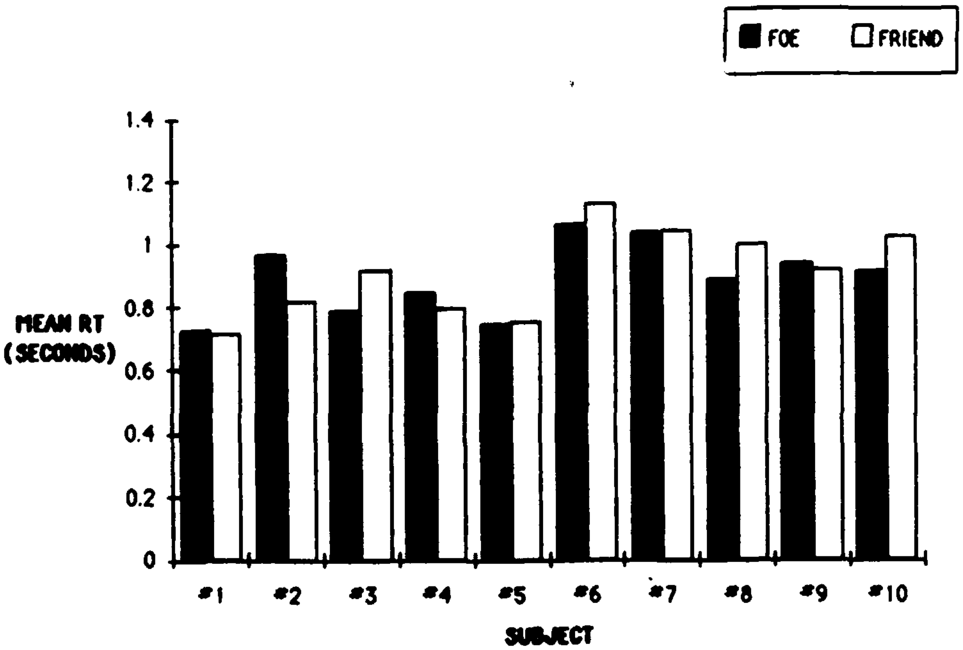


Figure 29
Within-Subject Mean RTs
Overall (100 ms)

4.4.4.1 Within-Subject Mean RT and Component

The performance of the subjects when presented with whole vehicle presentations can be seen in Figures 30 and 31. Figure 30 shows that 6 of the 10 subjects took longer to recognize friends at the 500 ms presentation times. The range of mean RTs for foe vehicle correct recognition was from .89 seconds for Subject 8, to 1.17 seconds for Subject 3. The range for friend vehicle correct recognitions was from a low of .85 seconds for Subject 5, to a high of 1.33 seconds for Subject 6.

The performance of each subject at the 100 ms presentation times is shown in Figure 31. All 10 of the subjects had lower mean RTs for correctly recognizing friend vehicles than they did at 500 ms. The range of the mean RTs went from .67 seconds by Subject 1 to 1.11 seconds by Subject 6. Only Subjects 6 and 8 took more time to recognize friends at 100 ms than foes. For foe vehicles, 7 of 10 subjects also had lower mean RTs for correctly recognizing the vehicles than they did at 500 ms. Subjects 8 and 9 had exactly the same mean RTs that they did at 500 ms, while Subject 7 had a higher mean RT than he did at 500 ms. At 100 ms, the range for foe vehicle mean RTs was from .77 seconds by Subject 5, to 1.08 seconds by Subject 7.

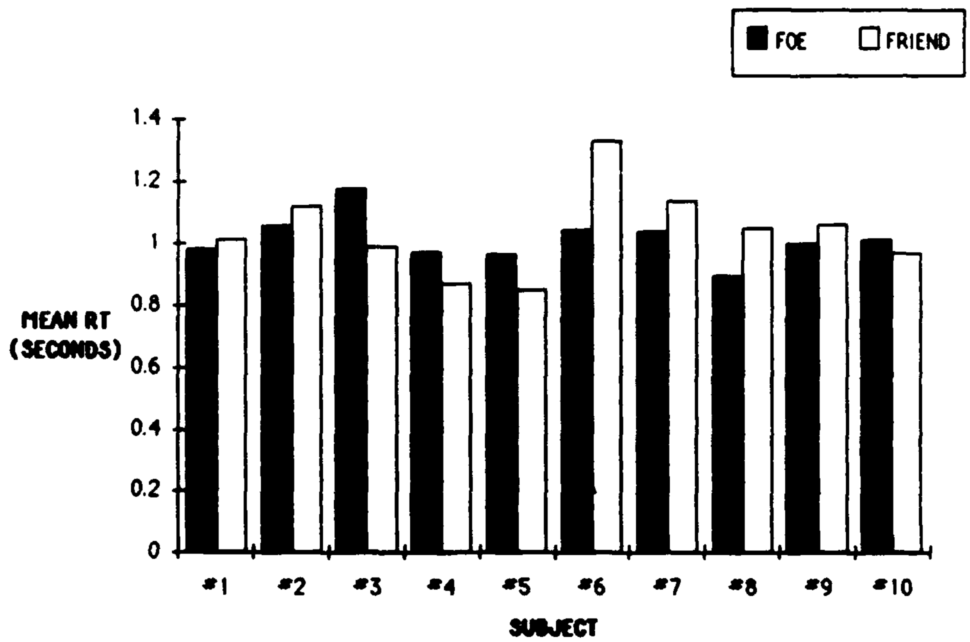


Figure 30
Within-Subject Mean RTs for
Whole Vehicles (500 ms)

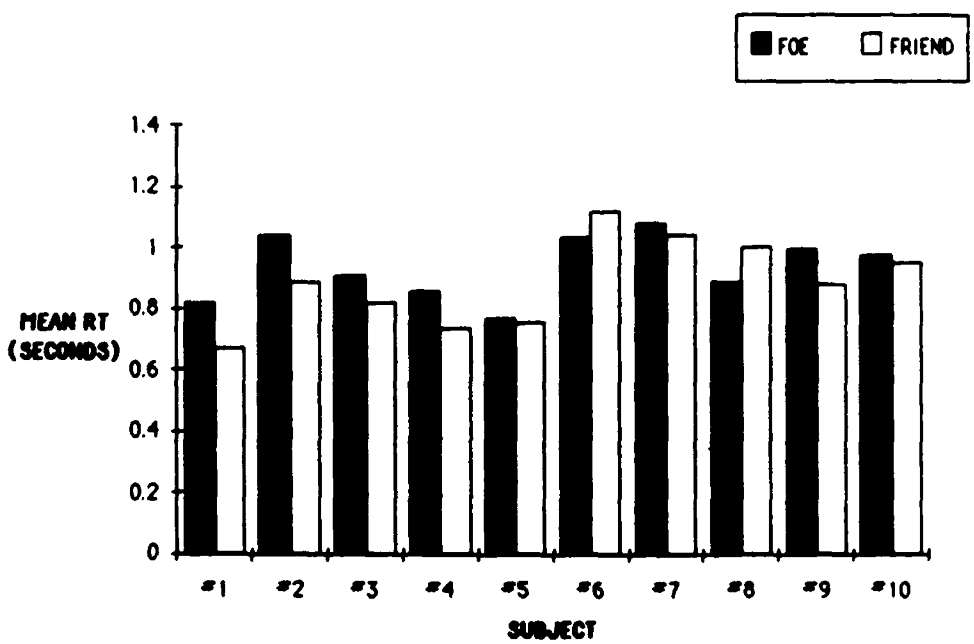


Figure 31
Within-Subject Mean RTs for
Whole Vehicles (100 ms)

When presented with the turret only presentations, the subjects had a general trend of recognizing foe vehicles quicker than friend vehicles. Figures 32 and 33 show the performance of each subject at the different presentation times. Figure 32 shows that, when presented with the turret only, 9 of 10 subjects recognized foe vehicles quicker than they did friend vehicles. The mean RTs for foe vehicle correct recognitions ranged from a low of .86 seconds by Subject 5, to a high of 1.13 seconds for Subject 9. The mean RTs for friend vehicle correct recognitions ranged from a low of .99 seconds by Subject 2, to a high of 1.34 seconds by Subject 6. There was only one exception to the trend of quicker foe vehicle correct recognitions, Subject 2 took longer to recognize the foe vehicles (1.12 seconds) than he did the friend vehicles (.99 seconds).

At presentation times of 100 ms (Figure 33), 9 of 10 of the subjects continued to recognize foe vehicles correctly more rapidly than they did friend vehicles. At 100 ms, all 10 subjects recognized foe vehicles correctly more rapidly than they did at 500 ms. The same was true for the recognition of friend vehicles by 9 of the 10 subjects. The range for foe vehicle correct recognitions at 100 ms went from a low mean RT of .66 seconds by Subject 1, to a high of 1.08 by

Subject 6. The range for friend vehicle correct recognitions went from a low mean RT of .76 seconds by Subject 5 to a high of 1.14 by Subject 10. Subject 2 again recognized friend vehicles (.77 seconds) correctly more rapidly than he did the foe vehicles (.88 seconds). At both 500 ms and 100 ms, Subject 2 was the only subject who had lower mean RTs for friend vehicles than he did for foes.

4.4.4.2 Within-Subject Mean RT and Viewing Angle

The analysis of mean RT and Viewing Angle is shown in Figures 34 to 37. Viewing Angle was shown to be significant with respect to mean RT ($F_{1,320}$=23.43, p<.001). The fact that viewing angle was significant with respect to mean RT continues to provide evidence that the processing of the different type vehicles may be occurring in different ways. The previously discussed trends with respect to how the friend and foe vehicles were best recognized are again true. In this situation, whether the view was a frontal or flank view had a impact on the mean RT.

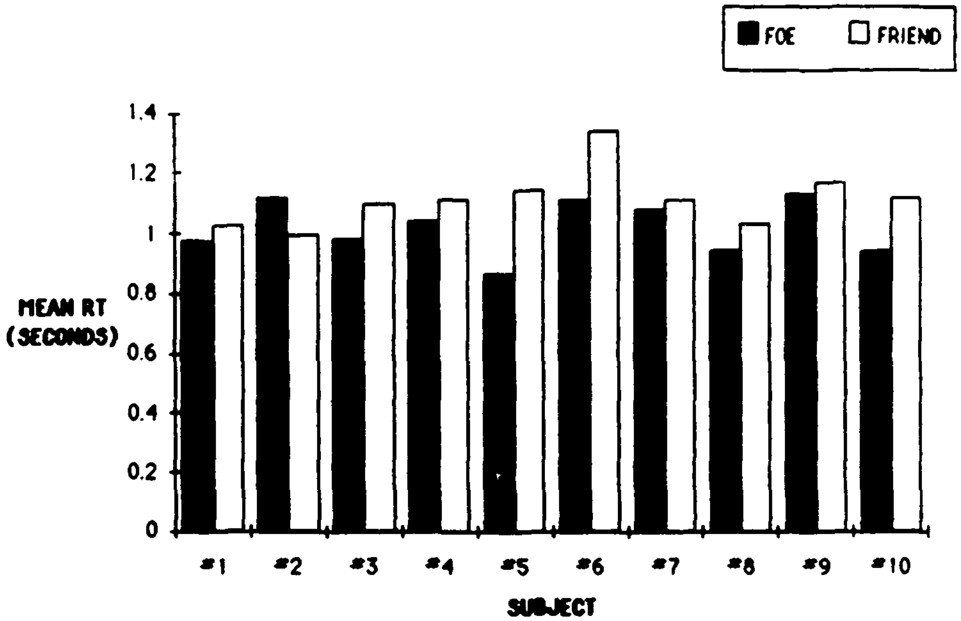


Figure 32
Within-Subject Mean RTs for
Turrets Only (500 ms)

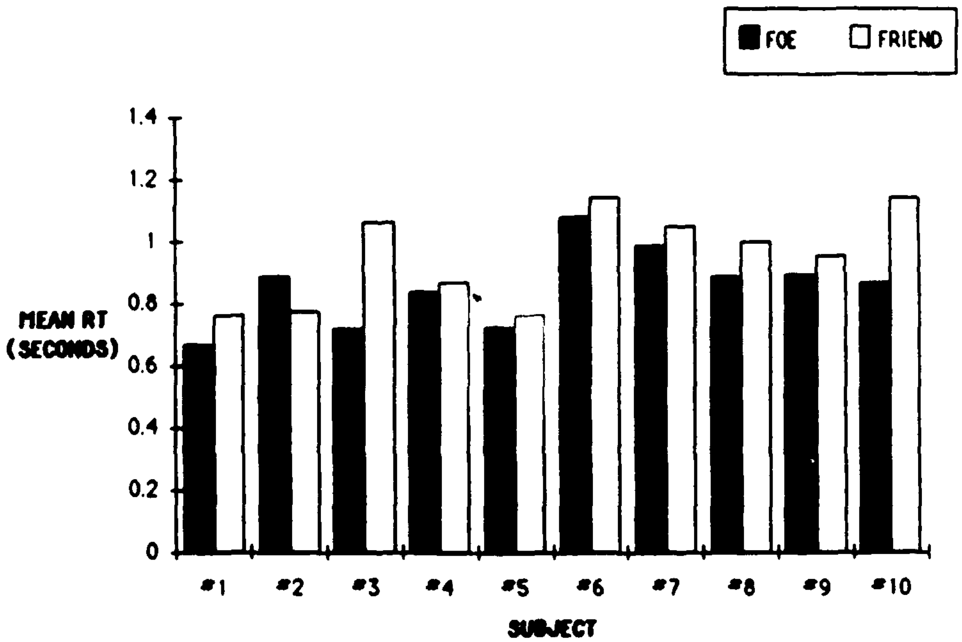


Figure 33
Within-Subject Mean RTs for
Turrets Only (100 ms)

The performance of the subjects when presented with frontal views of the vehicles can be seen in Figures 34 and 35. As shown in Figure 34, at 500 ms presentations, 7 of the 10 subjects had faster mean RTs for friend vehicle correct recognitions than they did for foe correct recognitions. The range of the mean RTs for friend correct recognitions went from a low of .99 seconds for Subject 4, to a high of 1.37 seconds for Subject 6. The range of mean RTs for foe vehicle correct recognitions went from a low of .95 seconds for Subject 8, to a high of 1.19 seconds for Subject 4. Only Subjects 6, 8, and 10 recognized the foe vehicles faster than the friend vehicles at 500 ms.

At the 100 ms presentations, as shown in Figure 35, all the subjects had faster mean RTs for both foe and friend vehicle correct recognitions. At the shorter presentation time, 5 of the 10 subjects were faster correctly recognizing friend vehicles. The range of mean RTs for friend vehicles was from a low of .73 seconds by Subject 1 to a high of 1.14 seconds by Subject 6. The range of mean RTs for the correct recognition of foe vehicles was from .78 seconds by Subject 3, to 1.11 seconds by Subject 6. Subjects 3, 5, 6, 8, and 10 had longer mean RTs for friend vehicle correct recognitions than they did for foe vehicles.

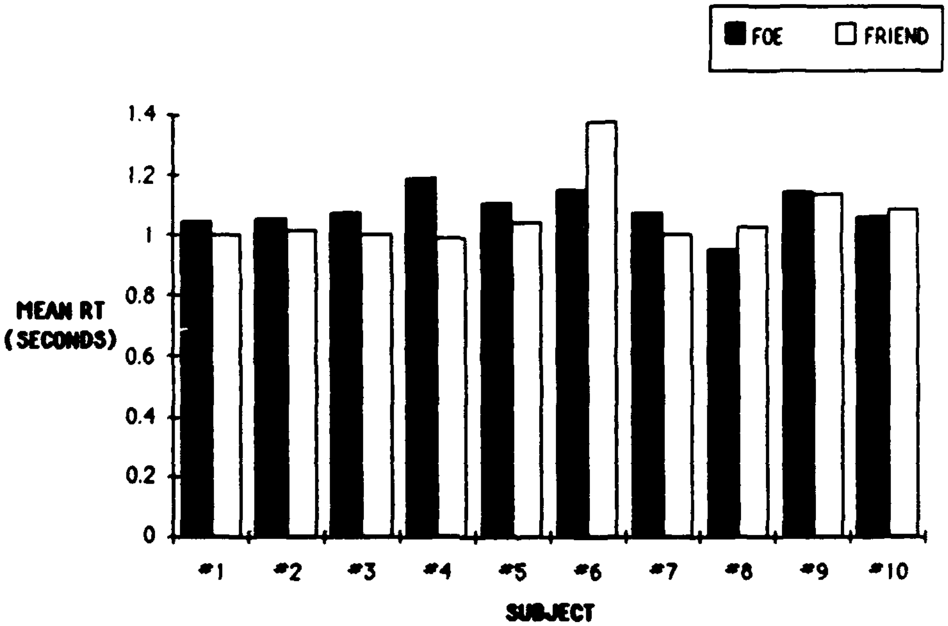


Figure 34
Within-Subject Mean RTs for
Frontal Views (500 ms)

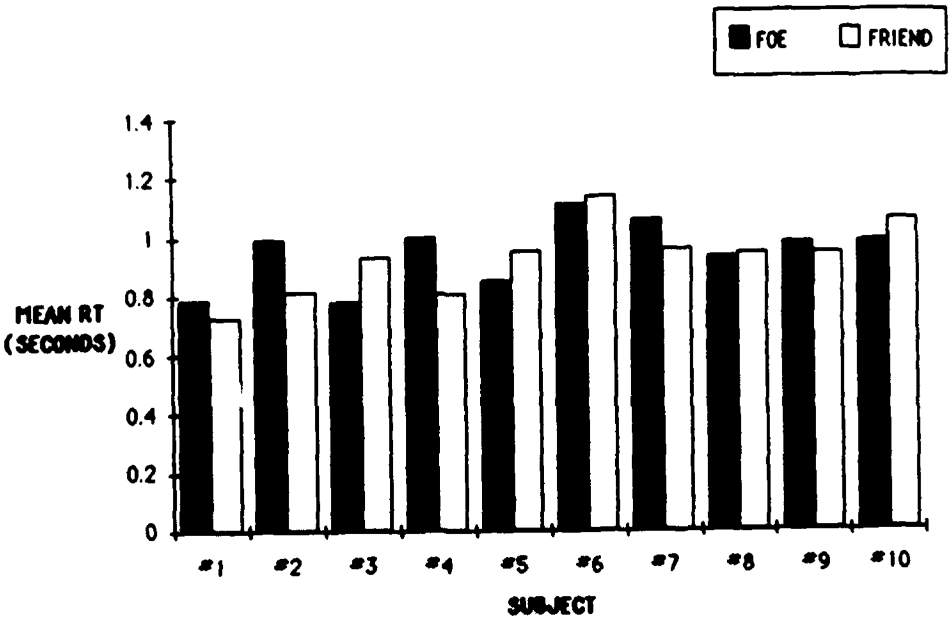


Figure 35
Within-Subject Mean RTs for
Frontal Views (100 ms)

The performance of the subjects when they were presented with flank views of the vehicles is shown in Figures 36 and 37. For the 500 ms presentations, 8 of the 10 subjects had faster mean RTs for foe vehicle correct recognitions than they did for the friend vehicle correct recognitions (Figure 36). Subjects 2 and 3 were the exceptions and had faster mean RTs for the correct friend vehicle recognitions. The range for the foe vehicle mean RTs for correct recognitions went from .77 seconds for Subject 5, to 1.12 seconds for Subject 2. The range of friend vehicle mean RTs for correct recognitions went from .91 seconds for Subject 5, to 1.29 seconds for Subject 6.

During the 100 ms presentations, 7 of the 10 subjects were still able to respond faster for the foe vehicle correct recognitions than for the friend vehicles (Figure 37). All the subjects responded faster for both friends and foes at 100 ms presentations than at 500 ms presentations. The range of mean RTs for foe vehicle correct recognitions was from a low of .70 seconds for Subject 1, to a high of 1.02 seconds for Subject 7. The range of mean RTs for the friend vehicle correct recognitions was from .65 seconds for Subject 5, to 1.13 seconds for Subject 7.

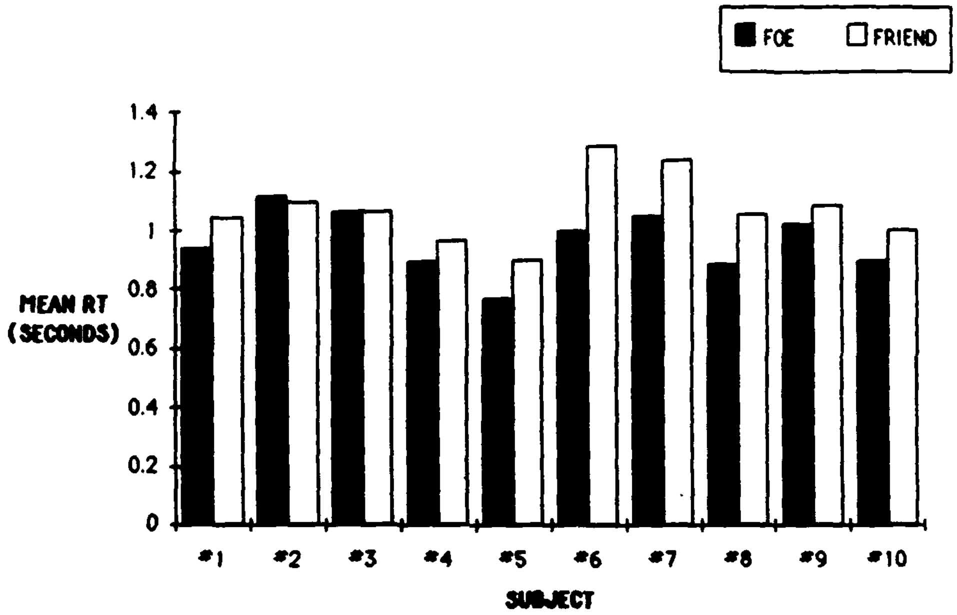


Figure 36
Within-Subject Mean RTs for
Flank Views (500 ms)

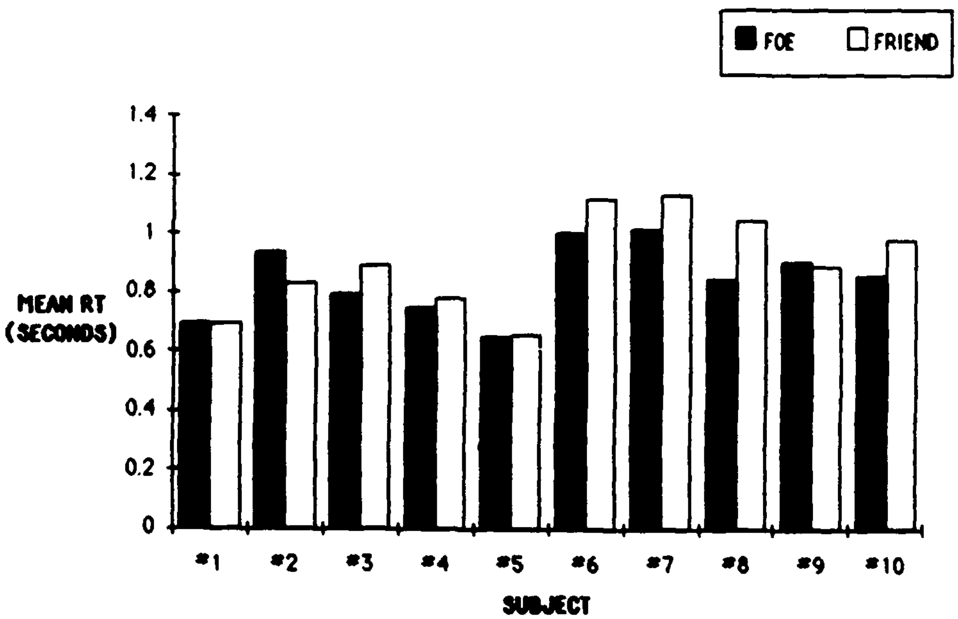
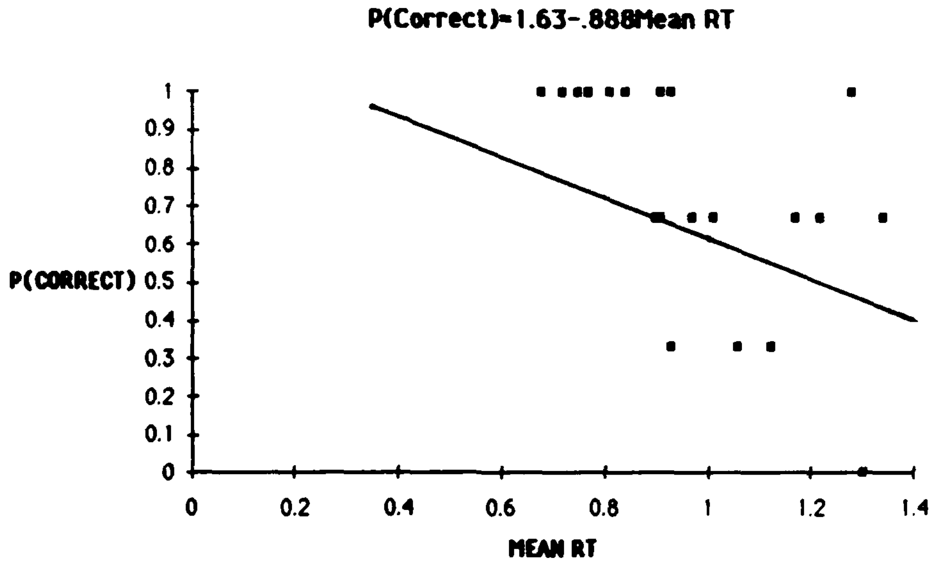


Figure 37
Within-Subject Mean RTs for
Flank Views (100 ms)

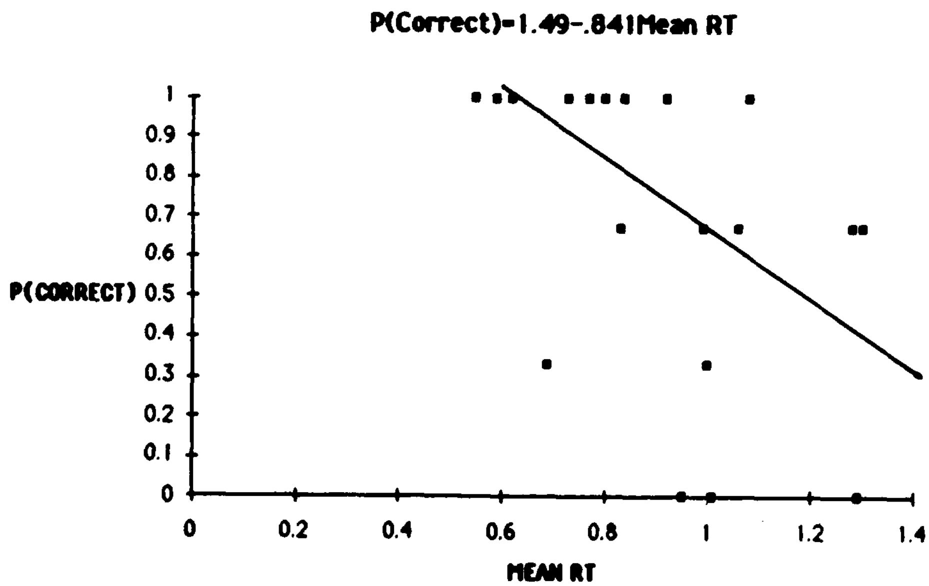
4.4.5 Within-Subject Plots and Regression Analysis

The plots of the data for each subject's proportion correct and mean RT created a series of scatterplots that were used to determine if a speed-accuracy tradeoff was occurring during the study. Two plots were constructed for each subject, one for friend responses and one for foe responses. If a speed-accuracy tradeoff were occurring, the plots would reveal a trend of decreasing proportion correct with the faster mean RTs. There was no trend indicating the presence of a speed-accuracy tradeoff for any of the subjects.

A regression analysis was performed on each of the plots. The results of the regression were that most of the regressions were not significant. Only five of the 20 regressions performed were significant. All of the regressions, whether significant or not, had negative slopes. Of the significant regressions, four were for plots of foe data for Subjects 4, 7, 9, and 10. The remaining significant regression was for the friend data for Subject 5. The plots of the significant regressions and the regression equation for each is shown in Figure 38.

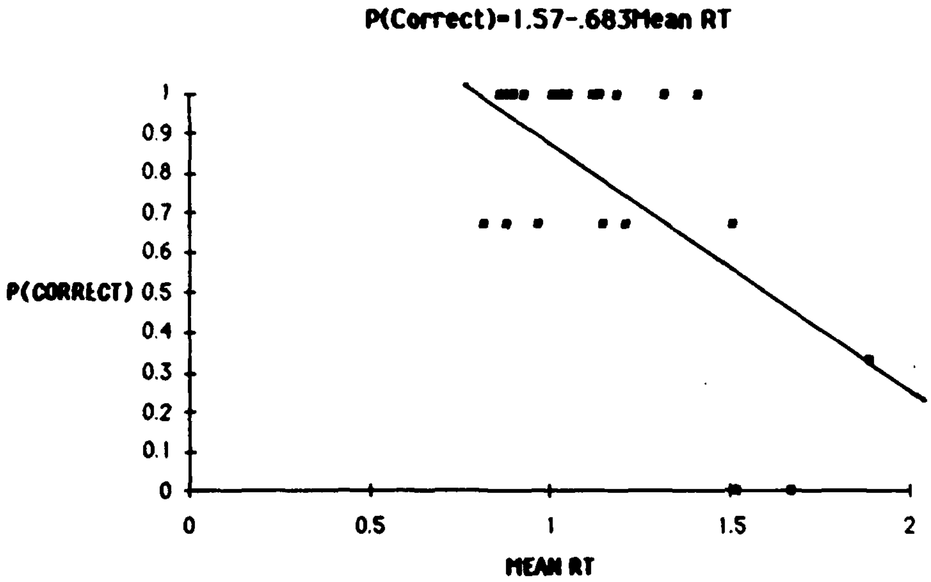


(a) Subject 4 (Foe)

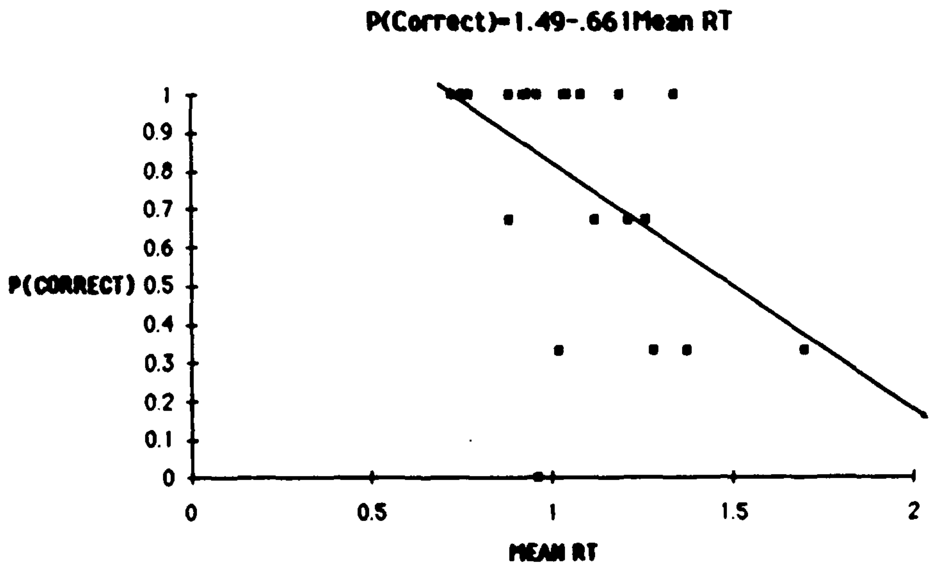


(b) Subject 5 (Friend)

Figure 38
Significant Regressions

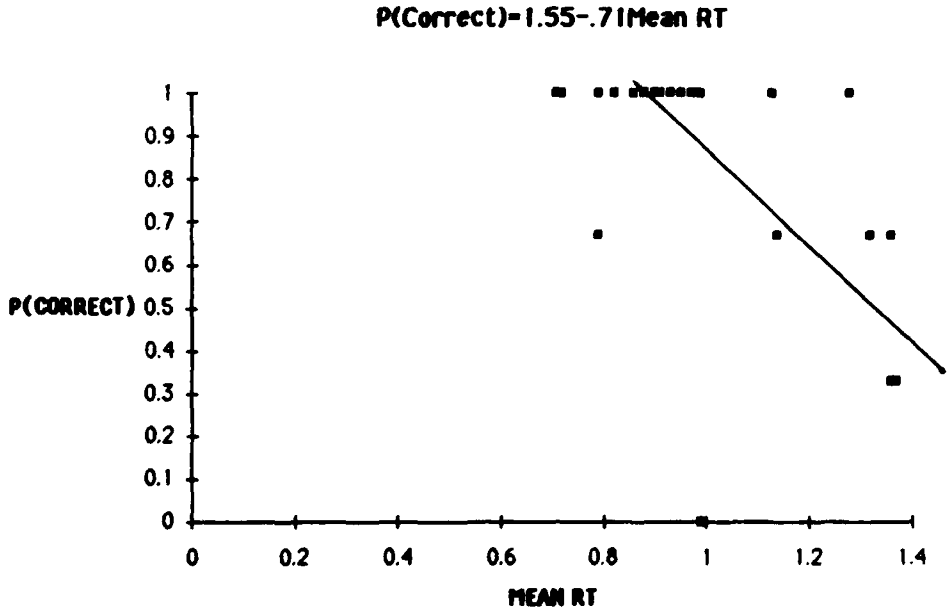


(c) Subject 7 (Foe)



(d) Subject 9 (Foe)

Figure 38
Continued



(e) Subject 10 (Foe)

Figure 38
Continued

Chapter 5

DISCUSSION

5.1 Subject Differences

It is clear that individual differences exist in the task of armored vehicle recognition. The subjects differed in all the dependent measures used for the study. Individual abilities to recognize friend and foe vehicles were evident in the study. The study also showed differences in the RTs for the subjects and the changes in sensitivity and individual criterion that existed for the different presentation conditions. The main effects and interactions that effected subject performance will be discussed below.

5.2 Main Effects

The main effects in the study all impacted on subject performance. As previously mentioned, subject performance varied between subject and the other main effects. The other main effects, when subjected to a between subject analysis, revealed a number of trends that indicate the type of cognitive processing that occurs when recognizing friend and foe vehicles. Friend vehicles were recognized at higher proportions than foe vehicles when all factors were combined by a difference of .85 to .81. While the recognition rates were higher for friend vehicles overall, the mean RT was also higher for friend vehicles at .99 seconds to .95 seconds for foes. When the component was examined, friend vehicles were recognized better as wholes than were foes. The difference in the proportion correct was .91 for friends to .76 for foes. Friend vehicles were also recognized better than the foes when frontal presentations were used. The difference in the proportion correct was .86 for friends to .71 for foes. As the presentation time decreased, the overall sensitivity (d') of the observers also decreased from 2.20 to 1.98. At the same time the overall criterion (β) increased from 1.20 to 1.68. This β increase indicates that as the presentation time decreased, the observers tended to become more liberal. There were clear differences between the processing of friend and foe vehicles based upon observing the patterns of the interactions that occurred. These differences indicated that the processing of the friend and foe vehicles was occurring in different ways, and at different presentation times, different strategies were used. How foes and friends differ will be discussed below.

5.3 Recognition of Foe Vehicles

When recognizing the foe vehicles, the observers did best, with a correct proportion of .93, when they were presented with a turret only view from the fla. At both presentation times, as more components were presented (whole vehicles), the proportion correct was less with only .76 of the vehicles correctly identified. At the 500 ms presentation, the number of components had very little effect on mean RT. The mean RT was 1.01 seconds for whole vehicles and 1.02 seconds for turrets only. As the presentation time was decreased to 100 ms, the mean RT decreased to .94 seconds for whole vehicles and .85 seconds for turrets only. The increase in RTs as the number of components increase does not support the RT trends found in the theory of Recognition by Component (Biederman, 1981). The turret only presentation for foes had the best foe mean RTs. Correspondingly, the highest mean RT occurred when the most components were presented for foe vehicles. The ability of the observers to recognize the foe vehicles correctly demonstrated the key role that parts played in overall recognition (Tversky and Hemenway, 1984). The observers directed their attention to the most informative part of the vehicle (Loftus and Mackworth, 1978).

The flank presentations for the foe vehicles represented the best viewing angle for recognition with an average proportion correct of .90. At a 500 ms presentation, only a proportion of .73 of the foes were correct recognized from the front compared to .96 from the flank. The same relationship was evident at the 100 ms presentation time with fronts recognized correctly at a proportion of .69 and flanks at .84. Since the flank view presents more cues, the evidence supports the concept that the greater the number of cues available, the better foe vehicles can be recognized (Kottas and Bessemer, 1981). While flank views increased accuracy, the mean RTs for flank views of foe vehicles were lower than for frontal views. At the 500 ms presentation, the RT difference was 1.08 seconds for front views to .97 seconds for flank views. As the presentation time was reduced to 100 ms, the RTs were also reduced to .95 seconds for frontal views and .84 seconds for flank views.

This evidence supports the concept that when attempting to recognize foe vehicles, the observer was not trying to match a specific mental representation or template. Instead, for the foe vehicles, the observers appeared to be looking for a specific critical component that would indicate that the vehicle presented was a foe vehicle. When these critical components were seen the subjects did the best correctly recognizing the vehicle. The flank views with turrets only provided the needed critical component and cues required to best recognize foe vehicles.

5.4 Recognition of Friend Vehicles

Recognition of friend vehicles differed from recognition of foe vehicles in what was important for a correct recognition. For friend vehicles, regardless of the presentation time, the more components presented (whole vehicles) the better the proportion of friend vehicle correctly recognized. The mean RTs for the friend vehicles were lower the greater number of components. When a single component was presented, the effect was a decrease in proportion correct and an increase in mean RT. This pattern held true for both of the presentation times.

As the number of available cues increased (flank view) for a friend vehicle, the proportion correct decreased. At 500 ms, the decrease was from a proportion of .90 for frontal views to a proportion of .86 for flank views. As the presentation time decreased to 100 ms, the proportion correct was still greater for frontal views at .82 compared to a proportion of .81 for flank views. The recognition of a friend vehicle depended much less on the number of cues available than did the recognition of a foe vehicles. The addition of more cues for the friend vehicles, appeared to induce a level of complexity that the observer did not need in order to correctly recognize the vehicle. The addition of more cues presented from a flank view of the friend vehicle only appeared to help mean RT at the 100 ms presentation, when the mean RT was .91 seconds for the flank view compared to .92 seconds for the front view. At the 500 ms presentation, mean RT was faster for the frontal presentation at 1.06 seconds compared to 1.08 for the flank view. The mean RT was faster for whole vehicle presentations at both presentation times. At 500 ms, whole vehicle presentations had a mean RT of 1.03 seconds versus a mean RT of 1.12 seconds for turrets only. At 100 ms, the mean RT difference was .88 seconds for whole vehicles and .95 seconds for turrets only.

The interaction of type and angle indicate that friend vehicle correct recognitions were much less affected by changes in angle than foe vehicles were. The change in proportion correct with the change in angle was .86 to .84. Changes in component adversely affected the friend vehicles when fewer were presented.

Overall, whole friend vehicles were correctly recognized at a proportion of .91, while the turrets only of friend vehicles were correctly recognized at a proportion of .79.

Recognition of the friend vehicles occurred in a way very different from the way foe vehicles were processed. When attempting to recognize the friend vehicles, the observers relied less on cues and more on total form. The recognition of the friend vehicles was also helped by the increased familiarity the subjects had with the friend vehicles. Increased familiarity improved recognition (Brooks and Watkins, 1989). The recognition of the friend vehicles appeared to rely more on the exact matching of a stored representation of the vehicle image. There does not appear to be the component-by-component processing that the evidence of this study supports for foe vehicle recognition.

5.5 Proposed Processing Models

Recognition of friend and foe vehicles was performed through different processes. This type of dual-process theory is not uncommon. One example of a model that proposes a dual-process is a template-processing identity reporter for S responses and a slower serial/self-terminating model for D responses

(Bamber, 1969).

The model used by the subjects in this study used a template match for friend vehicles and a variation of Biederman's Recognition by Component (RBC) theory for the recognition of foe vehicles. Subject's performance was very different for either a friend or a foe vehicle. The recognition of a friend vehicle was a more pure template-matching process. The subjects were able to match whole form presentations to stored representations more efficiently than they could component presentations. The simpler the image presentation the better the subjects did. The more complexity that was introduced by the addition of more cues did not improve performance. This proves the presence of a criterion effect that was used for the friend vehicles. Beyond the criterion the addition of more information does not help with recognition performance. The stored representation was in a very simple form and that the additional cues only delayed the template match. A contributing factor to the ability to use the template match was the familiarity with the friend vehicles that the observers had.

A variation of Biederman's RBC theory was supported for processing and recognition of foe vehicles. The foe vehicle was a less familiar object than the friend vehicle. A single critical component, the turret, was very important for the correct recognition of foe vehicles. Along with finding the critical component, the more cues available on that component the better the recognition task was performed. The addition of other components did not improve recognition performance. A proposed model of foe vehicle recognition is shown in Figure 39. The model contains some of the elements of Biederman's RBC model. There are direct relationships between the proposed model and the information processing model proposed by Wickens (Wickens, 1984). The proposed model contains elements of bottom-up and top-down processing. All the initial components of the model, from edge extraction to determination of components, follow Biederman's model. These components are primarily the perceptual elements of the model. As the visual stimulus of the vehicle is transferred into the short term sensory store, attentional resources are directed to the image to break it into components. At the stage of determining the components, the transfer of information from long-term to working memory begins. This transfer of information is necessary because the recognition of the components, with regard to what part of the foe vehicle they are, will be based on this information. The identification of the turret is a decision that must be made based upon both the bottom-up information of the visual stimuli and the top-down factors shaped by the stored representation and knowledge of the situation. Once the turret has been identified, it is matched to the stored representation now in working memory. Once a match is made, the vehicle is recognized as a foe. After the recognition of the vehicle as a foe, the response execution element of Wickens' model would begin.

The recognition of the vehicle is then based upon the quality of the match of the turret to the stored mental representation. The key difference between this model and the RBC model proposed by Biederman is that the addition of more components does not improve either recognition or mean RT. This model for foe vehicle recognition may be relevant because the foe vehicle represented a lesser known quantity. The objects used by Biederman were all relatively well-known objects. When objects are not common, the principles that Biederman stated may not be relevant. Another factor explaining why foe vehicle recognition did not support Biederman's theory was the requirement not to just recognize an object (e.g. as a tank), but also to determine it as one of two groups, friend or foe.

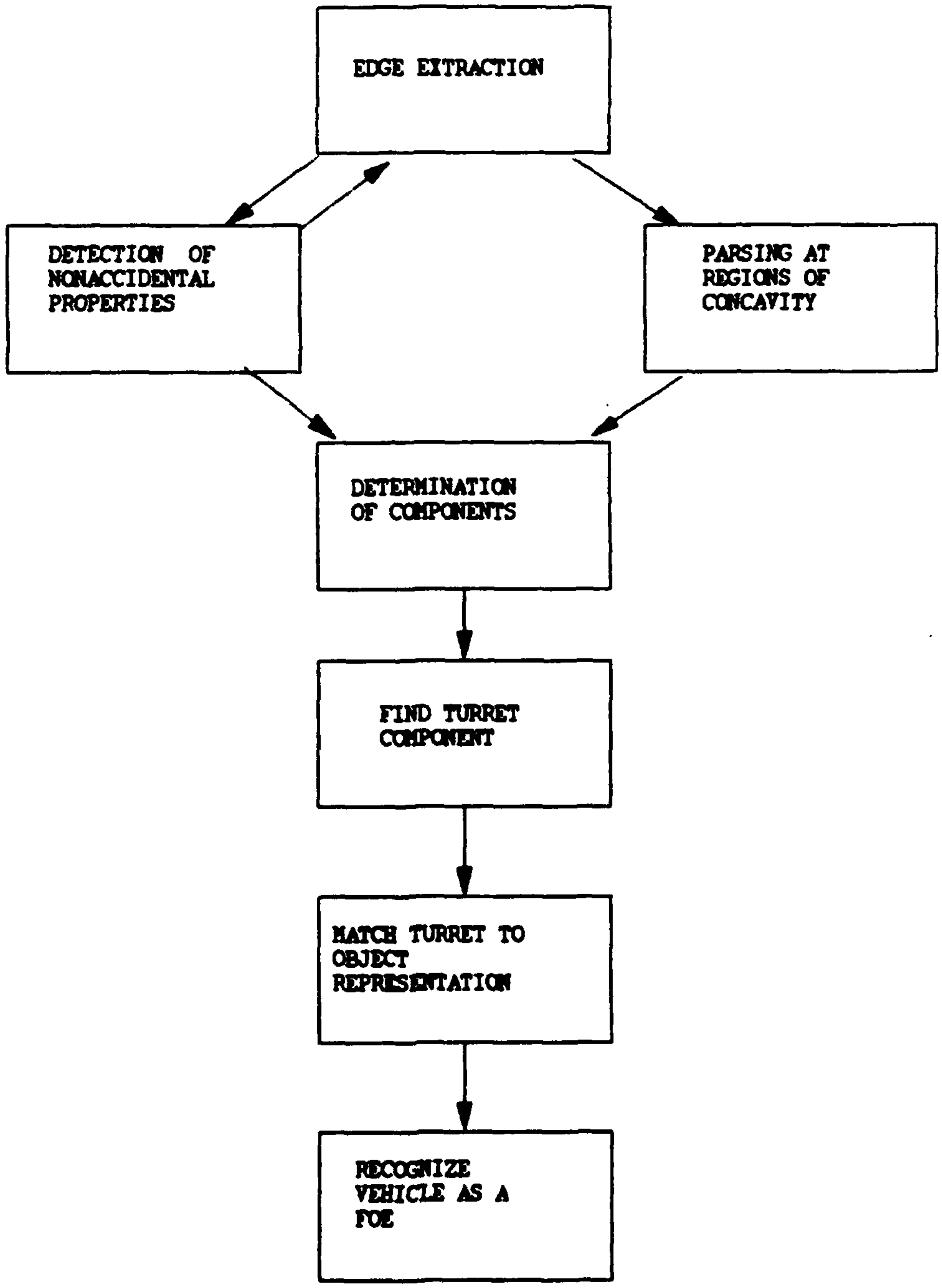


Figure 39
Proposed Foe Vehicle Recognition Model

5.6 Implications for Recognition Training

The results of this study have several implications that may be able to improve the ability to discriminate between friend and foe vehicle recognition. When training soldiers to recognize foe vehicles, it is relevant to concentrate the training efforts on the turret as opposed to whole form recognition training. Most observers will have less familiarity with foes because they do not see them on a regular basis. It would be would be more beneficial to concentrate the bulk of the training on the single critical component that the recognition decision will be based upon.

The training of friend vehicles would be best accomplished using a combination of whole form presentations with emphasis on the turret as a critical component. The familiarity that the soldiers have with friend vehicles would allow the adequate formation of a mental template. The training of friend vehicles could possibly be improved by repeated tachistoscopic presentations, thereby strengthening the access to the stored mental template. It is also important to develop a strong template for the turret-only since the vehicle will not always be seen in its total form. The training of military equipment using tachistoscopic presentations is not a new idea. During the Second World War, Dr. Samuel Renshaw used it to train aircrews in aircraft recognition. Reviews of the data showed that total forms alone were not enough. The subjects wanted some feature training to verify their initial recognition decisions that seeing the aircraft as a total form

caused them to make. The features were more for verification than recognition (Gibson, 1947). The current study showed that whole forms are most important for friend vehicles. However, the addition of verification through the turret could be the critical extra step that would prevent fratricide incidents.

5.7 Suggested Topics of Further Investigation

While the results of this study provide a degree of evidence for the concept of two types of processing models, additional work needs to be done in order to verify that this was what was actually occurring. This same experiment with the inclusion of eye tracking data would provide the additional evidence required. The eye tracking data of foe vehicles should show a pattern of eye movements centered primarily around the turret. The pattern for friend vehicles should be around the exterior contours of the vehicle. If the eye tracking data would show these two distinct patterns, depending on the type of vehicle used, the proposed theory would of two separate models would be supported.

Another topic of research that should be examined is a comparison of separate training programs. The programs could compare how well soldiers can recognize vehicles if trained either on total forms, turrets only, and a combination of both. The current study indicates that the best performance for foe recognition would be with turrets only and the best with friends would probably be a combination of total form with some emphasis on the turret as a critical feature used to verify the initial total form recognition decision.

5.8 Additional Applications

The concept of the dual process for recognition has a number of additional military applications. The recognition of aircraft presents many of the same problems that vehicle recognition does. Adopting a training strategy that emphasizes components for foe aircraft would improve performance. The whole form recognition of friend aircraft can be enhanced through repeated exposure and greater familiarization.

Within the civilian sector, this training strategy can be applied to most inspection tasks. If a new product is being introduced, the best way to train the inspector will be with an emphasis on parts and components. As inspectors become more familiar with the product, they would adopt more of a whole form recognition strategy. This same approach should be applied to the training of new inspectors in any task that requires recognition of a specific object. The training strategy must focus initially on parts and components since the object will be unfamiliar to the new inspector. As inspectors become more familiar with the object through increased exposure, they will adopt the strategy that relies less on parts and more on the whole form recognition of the object with parts used to verify the initial decision.

REFERENCES

Attneave, F. (1954), "Some informational aspects of visual perception," Psychological Review, 61, pp. 183-193.

Baker, C.A., Morris, D.F., and Steedman, W.C. (1960), "Target recognition on complex displays," Human Factors, 2(2), pp. 51-61.

Bamber, D. (1969), "Reaction times and error rates for "same"-"different" judgements of multidimensional stimuli," Perception and Psychophysics, 61, pp. 169-174.

Biederman, I. (1987), "Recognition by components: a theory of human image understanding," Psychological Review, 94(2), pp. 115-147.

Biederman I. and Ju, G. (1988), "Surface versus edge-based determinants of visual recognition," Cognitive Psychology, 20, pp. 38-64.

Biederman, I., Mezzanote, R.J., Rabinowitz, J.C., Francoloini, C.M., and Plude, D. (1981), "Detecting the unexpected in photointerpretation," Human Factors, 23(2), pp. 153-164.

Bobrow, D. and Norman, D. (1975), "On data-limited and resource-limited processing," Cognitive Psychology, 7, pp. 40-66.

Bower, G.H. and Glass, A. (1976), "Structural units and the redintegrative power of picture fragments," Journal of Experimental Psychology: Human Memory and Learning, 2, pp. 456-466.

Broadbent, D.E. (1958), Perception and Communication, London: Pergamon Press.

Broadbent, D.E. (1982), "Task combination and selective intake of information," Acta Psychologica, 50, pp. 253-290.

Brooks, J.O. and Watkins, M.J. (1989), "Recognition memory and the mere exposure effect," Journal of Experimental Psychology: Learning, Memory, and Cognition, 15(5), pp. 968-976.

Card, S.K., Moran, T.P., and Newell, A. (1986), "The model human processor," Handbook of Perception and Human Performance, 2, pp. 45-1-45-35.

Chipman, S.F. (1977), "Complexity and structure in visual pattern," Journal of Experimental Psychology: General, 106(3), pp. 269-301.

Craig, A. (1984), "Human engineering: the control of vigilance," Sustained Attention in Human Performance, ed. J.S. Warm, J. Wiley and Sons Ltd.

Foskett, R.J., Baldwin, R.J., and Kubala, A.L. (1978), "The detection of ranges of features of armored vehicles," Technical Report 78-A37.

Geisler, W.S. (1989), "Sequential ideal-observer analysis of visual discriminations," Psychological Review, 96, pp. 267-314.

Gibson, J.J. (1947), Motion Picture Testing and Research, Report #7, Washington,DC: U.S. Government Printing Office.

Green, D.M. and Swets, J.A. (1966), Signal Detection Theory and Psychophysics, New York:Wiley.

Hake, H.W. (1957), "Contribution of psychology to the study of pattern vision," USAW WADC Technical Report, pp. 57-261.

Harmeyer, G.H. and Antal,J.F. (1992), "Fire discipline and fratricide," Army, 42(3), pp. 26-28.

Hoffman, D.D. and Richards, W.A. (1982), "Representing smooth planes curves for visual recognition," Proceedings of American Association Artificial Intelligence, pp. 5-8.

Hoffman, D.D. and Richards, W.A. (1985), "Parts of recognition," Cognition, 18, pp. 65-96.

Johnson, R.M. (1981), "An information processing model of target acquisition," Proceedings of the Human Factors Society, 31st Annual Meeting, pp. 267-271.

Jung, E.S. and Goldberg, J.H. (1980), "Effects of task loading and time on recognition memory performance," Proceedings of the Human Factors Society, 31st Annual Meeting, pp. 373-377.

Keele, S.W. (1972),"Attention demands of memory retrieval," Journal of Experimental Psychology, 93, pp. 245-248.

Kottas, B.L. and Bessemer, D.W. (1981), "Behavioral bases for determining vehicle detailing in simulation displays," Proceedings Interservice/Industry Equipment Conference, 2d Annual, pp. 65-69.

Kottas, B.L. and Bessemer, D.L. (1981), "An approach to determining critical recognition features: detectability of armored vehicle features under visibility variations," Working Paper FKFU 81-1, pp. 1-22.

Krause, R.H., (1965) "Interpretation of complex images: literature survey," Goodyear Engineering Report 10830, Rev A.

Loftus, G.R. and Mackworth, N.H. (1978), "Cognitive determinants of fixation location during picture viewing," Journal of Experimental Psychology: Human Perception and Performance, 4(4), pp. 565-572.

Mackworth, N.H. (1948), "The breakdown of vigilance during prolonged visual search," Quarterly Journal of Experimental Psychology, 1, pp. 5-61.

Mackworth, N.H. and Morandi, A.J. (1967), "The gaze selects informative details within pictures," Perception and Psychophysics, 2(11), pp. 547-551.

Maxey, J.L., Ton, W.H., Warnick, W.L., and Kubala, A.L. (1976), "Target presentation methodology for tactical field evaluations," Research Problem Review 76-11.

Miller, G.A. (1956), "The magical number seven plus or minus two: some limits on our capacity for processing information," Psychological Review, 63, pp. 81-97.

Neisser, U. (1969), "Selective reading: a method for the study of visual attention," 19th Congress of Psychology, London.

Neisser, U. and Becklen, R. (1975), "Selective looking: attending to visually specified events," Cognitive Psychology, 7, pp. 480-494.

Nelson, T.O., Metzler, J., and Reed, D.A. (1974), "Role of details in long-term recognition of pictures and verbal descriptions," Journal of Experimental Psychology, 102, pp. 184-186.

Palmer, S.L., (1977), "Hierarchal structure in perceptual representation," Cognitive Psychology, 9, pp. 441-474.

Parasuraman, R. (1980), "Applications of signal detection theory in monitoring performance and medical diagnosis," Proceedings of the Human Factors Society, 24th Annual Meeting.

Pezdek,K., Maki, R., Valencia-Laver, D., Whetstone, T., and Stoeckert, J. (1988), "Picture memory: recognizing added and deleted details," Journal of Experimental Psychology: Learning, Memory, and Cognition, 14(3), pp. 468-476.

Pollack, I. and Spence, D. (1968), "Subjective pictorial information and visual search," Perception and Psychophysics, 3(1B), pp. 41-44.

Rabbit, P.M.A. (1964), "Ignoring irrelevant information," British Journal of Psychology, 55(4), pp. 403-414.

Rock, I., Halper, F. and Clayton, T., (1972), "The perception and recognition of complex figures," Cognitive Psychology, 3, pp. 655-673.

Rosch, E., Mervis, C.B., Gray, W., Johnson, D., and Boyes-Braem, P. (1976), "Basic objects in natural categories," Cognitive Psychology, 8, pp. 382-439.

Seamon, J.G., Marsh, R.L. and Brody, N. (1984), "Critical importance of exposure duration for affective discrimination of stimuli that are not recognized," Journal of Experimental Psychology: Learning, Memory, and Cognition, 10(3), pp. 465-469.

Sperling, G. (1960), "The information available in brief visual presentations," Psychological Monographs, 74, pp. 1-29.

Sperling, G. (1971),"Extremely rapid visual search," Science, 174, pp. 307-311.

Sternberg, S. (1969), "Memory-scanning: mental processes revealed by reaction time experiments," American Scientist, 53(5), pp. 421-457.

Sternberg, S. (1975), "Memory scanning: new findings and current controversies," Quarterly Journal of Experimental Psychology, 27, pp. 1-32.

Treisman, A.M. (1969), "Strategies and models of selective attention," Psychological Review, 76 (3). pp. 282-299.

Tversky, B. and Hemenway, K. (1984), "Objects, parts, and categories," Journal of Experimental Psychology: General, 113(2), pp. 169-191.

Ullman, S. (1984), "Visual routines," Cognition, 18, pp. 97-159.

Wachtel, P.L. (1967), "Concepts of broad and narrow attention," Psychological Bulletin, 68, pp. 417-419.

Warnick, W.L. and Smith, N.D. (1989), "Summary of research on combat vehicle identification completed at ARI Fort Hood Unit," Research Report 1540, pp. 71-74.

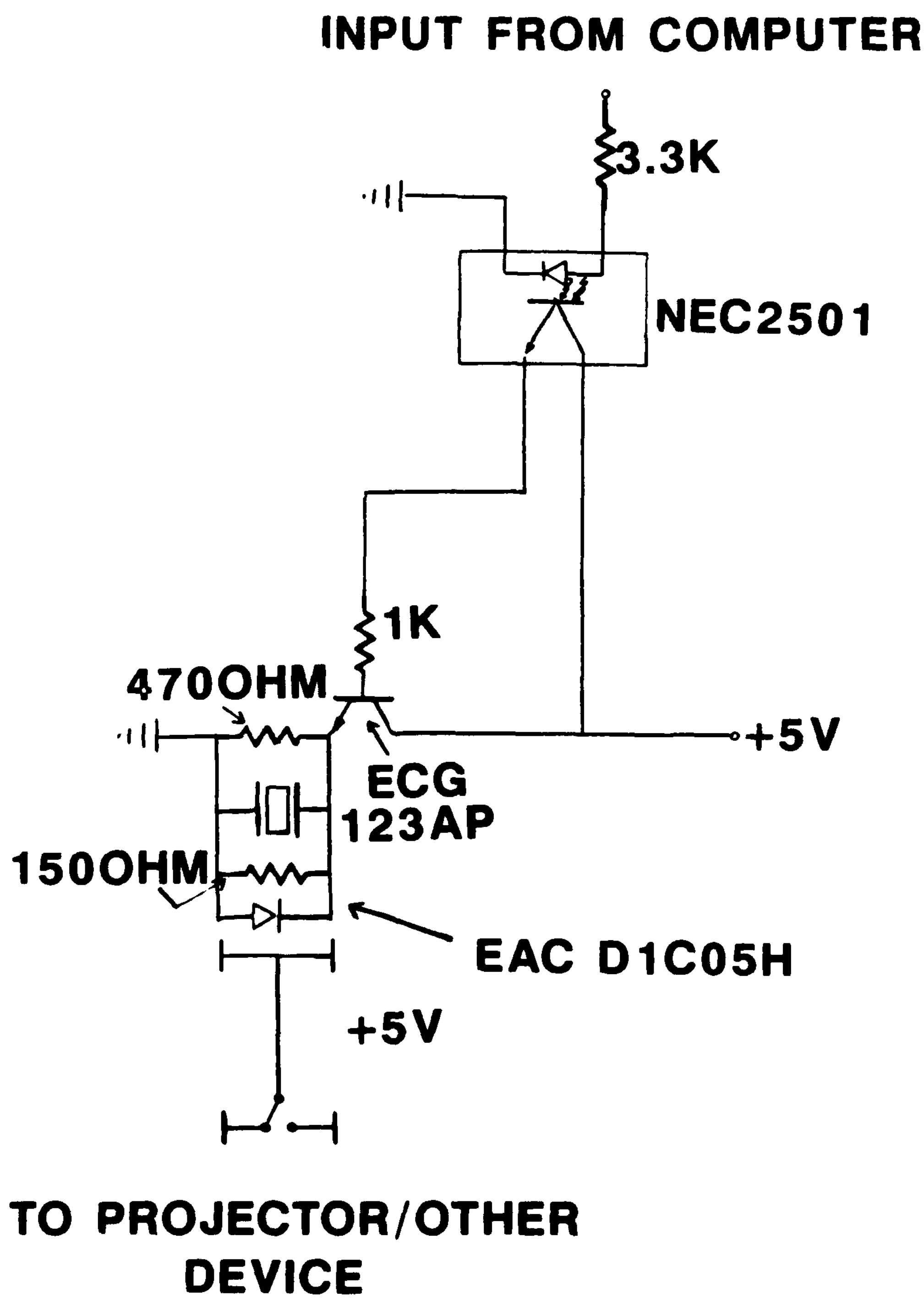
Wickens, C.D., (1984), Engineering Psychology and Human Performance, Glenview, Ill.: Scott, Foresman and Co.

Witkin, A.P. and Tennenbaum, J.M. (1983), "On the role of structure of vision," Human and Machine Vision, New York: Academic Press.

Zajonc, R.B. (1980), "Feeling and thinking: preferences need no inferences," American Psychologist, 35, pp. 151-175.

Appendix A

INTERFACE CIRCUITRY DIAGRAM


INPUT FROM COMPUTER
3.3K
NEC2501
1K
470OHM
+5V
ECG
123AP
150OHM
EAC D1C05H
+5V
TO PROJECTOR/OTHER
DEVICE

Appendix B

PROGRAM LISTING

```
'*****************************************************************************
'*                        Tachistoscope Controller                           *
'*                                   by                                      *
'*                             R. Darin Ellis                                *
'*                                                                           *
'*                              version 1.0                                  *
'*                               2/18/92                                     *
'*****************************************************************************


DEFINT A-D
DECLARE SUB mouses (a, b, c, d)
DIM b$(50), rt(50), rtsqr(50)
DIM tray1$(50), tray2$(50), tray3$(50), tray$(50)
DIM acc$(50)


'*** Tray #1 *** Tray #2 *** Tray #3
DATA l,r,r,r,l,l,r,r,l,r,l,r,l,r,l,l,l,r,l,r,l,r,l,r

DATA r,l,r,r,l,l,l,l,r,l,r,r,l,r,r,r,l,r,l,l,r,r,l,l

DATA l,r,l,r,r,r,r,l,r,l,r,l,l,r,l,r,l,r,l,l,r,l,l,r

        i = 0
        FOR i = 1 TO 24
                READ tray1$(i)
                'PRINT tray$(i);
        NEXT i
        i = 0
        FOR i = 1 TO 24
                READ tray2$(i)
                'PRINT tray$(i);
        NEXT i
        i = 0
        FOR i = 1 TO 24
                READ tray3$(i)
                'PRINT tray$(i);
        NEXT i



'*****************************************************************
CLS
'ON ERROR GOTO handler
TIMER ON

PRINT "Enter a Y to open an old data file -- or --"
INPUT "Enter any other key to run a new subject...", y$
```

```
IF y$ = "y" OR y$ = "Y" THEN GOSUB getdata


INPUT "Subject identifier = ", subject$
INPUT "Exposure time = ", exposure
INPUT "Tray # = "; traynum

'INPUT "Inter-trial time = ",
iti = 5
'INPUT "Warning interval = ",
wi = 1
'INPUT "Number of trials per block = ",
nt = 24

        PRINT
        PRINT "Hit any key to begin a trial block"
        a$ = ""
5     a$ = INKEY$: IF a$ = "" THEN 5

'****** L is a friend, R foe **********


SELECT CASE traynum

CASE 1
        '*** data for tray 1 ****
        i = 0
        FOR i = 1 TO 24
                tray$(i) = tray1$(i)
        NEXT i

CASE 2
        '*** data for tray 2 ****
        i = 0
        FOR i = 1 TO 24
                tray$(i) = tray2$(i)
        NEXT i

CASE 3
        '*** data for tray 3 ****
        i = 0
        FOR i = 1 TO 24
                tray$(i) = tray3$(i)
        NEXT i

END SELECT

'*************** Main Program *********************************************

        i = 0: j = 0
        IF exposure = .1 THEN GOSUB hundredmsec ELSE GOSUB normal
        GOSUB eval
```

```
        GOSUB save
99      END



'**************************************************************************
normal:
OUT 888, 0

j = 0
FOR j = 1 TO nt
        CLS : b = 0: check = 0: response = 0
        PRINT "inter-trial time": BEEP: SLEEP iti
        PRINT "CLEAR"
        OUT 888, 0
        PRINT "ADVANCE"
        OUT 888, 4: FOR k = 1 TO 1500: NEXT k

        PRINT "CLEAR"
        OUT 888, 0
        PRINT "warning"
        PRINT "check"; check: PRINT "response"; response
        PRINT "B$"; j; b$(j): BEEP: BEEP: BEEP: SLEEP wi

        PRINT "OPEN"
        a = 5: b = 0: CALL mouses(a, b, c, d)   '*** clear count of extra
        a = 5: b = 1: CALL mouses(a, b, c, d)  '*** button presses

        start = TIMER
        OUT 888, 2
        DO UNTIL check > exposure OR response > 0
                check = TIMER - start
                a = 5: b = 0: CALL mouses(a, b, c, d)   '*** check L button
                IF b > 0 THEN
                        b$(j) = "l": rt(j) = TIMER - start
                ELSE  '*** If no L presses then check R presses
                        a = 5: b = 1: CALL mouses(a, b, c, d)
                        IF b > 0 THEN b$(j) = "r": rt(j) = TIMER - start
                END IF
                IF b$(j) <> "" THEN response = 1
100     LOOP
        OUT 888, 0
        PRINT "CLOSE"
        IF response = 0 THEN GOTO 200 ELSE GOTO 300
200     'PRINT "I'm still waiting"
        DO UNTIL response > 0 OR check > 2.5
                check = TIMER - start
                a = 5: b = 0: CALL mouses(a, b, c, d)   '*** check L button
                IF b > 0 THEN
                        b$(j) = "l": rt(j) = TIMER - start
                ELSE  '*** If no L presses then check R presses
```

```
                    a = 5: b = 1: CALL mouses(a, b, c, d)
                    IF b > 0 THEN b$(j) = "r": rt(j) = TIMER - start
               END IF
               IF b$(j) <> "" THEN response = 1
          LOOP
          IF check > 2.5 THEN b$(j) = "n"
          IF check > 2.5 THEN rt(j) = 2.5

300 NEXT j
RETURN




'******************************************************************************

hundredmsec:   '***** This subroutine is for very short presentation times *****

OUT 888, 0
j = 0
FOR j = 1 TO nt
          CLS : b = 0: check = 0: response = 0: m = 0
          PRINT "inter-trial time": BEEP: SLEEP iti
          PRINT "CLEAR"
          OUT 888, 0
          PRINT "ADVANCE"
          OUT 888, 4: FOR k = 1 TO 1500: NEXT k

          PRINT "CLEAR"
          OUT 888, 0
          PRINT "warning"
          PRINT "check"; check: PRINT "response"; response
          PRINT "B$"; j; b$(j): BEEP: BEEP: BEEP: SLEEP wi

          PRINT "OPEN"
          a = 5: b = 0: CALL mouses(a, b, c, d)   '*** clear count of extra
          a = 5: b = 1: CALL mouses(a, b, c, d)   '*** button presses

          start = TIMER
          OUT 888, 2: FOR m = 1 TO 200: NEXT m: OUT 888, 0
         ' DO UNTIL check > exposure
         '        check = TIMER - start
500      ' LOOP
         'OUT 888, 0
         'PRINT "CLOSE"
600      'PRINT "I'm still waiting"
          DO UNTIL response > 0 OR check > 2.5
               check = TIMER - start
               a = 5: b = 0: CALL mouses(a, b, c, d)   '*** check L button
               IF b > 0 THEN
                    b$(j) = "l": rt(j) = TIMER - start
```

```
                ELSE  '*** If no L presses then check R presses
                        a = 5: b = 1: CALL mouses(a, b, c, d)
                        IF b > 0 THEN b$(j) = "r": rt(j) = TIMER - start
                END IF
                IF b$(j) <> "" THEN response = 1
        LOOP
        IF check > 2.5 THEN b$(j) = "n"
        IF check > 2.5 THEN rt(j) = 2.5

700 NEXT j
RETURN



'*************************************************************************
eval:
        i = 0
        CLS : FOR i = 1 TO nt: PRINT "b$"; i; b$(i), "rt"; rt(i): NEXT i
        FOR i = 1 TO nt
                rtsum = rtsum + rt(i)
                rtsqr = rtsqr + (rt(i) * rt(i))
        NEXT i

        rtmean = rtsum / nt
        rtsumsqr = rtsum * rtsum
        rtvariance = (1 / (nt - 1)) * (rtsqr - ((rtsumsqr) / nt))
        rtsd = SQR(rtvariance)
        PRINT
        PRINT "Mean RT = "; rtmean, "RT sd = "; rtsd


'******************************  l=friend   r=foe   *****************
        i = 0
        FOR i = 1 TO 24
                IF b$(i) = "l" AND tray$(i) = "l" THEN
                        acc$(i) = "C"
                        numcas = numcas + 1
                ELSEIF b$(i) = "l" AND tray$(i) = "r" THEN
                        acc$(i) = "M"
                        nummisses = nummisses + 1
                ELSEIF b$(i) = "r" AND tray$(i) = "l" THEN
                        acc$(i) = "F"
                        numfas = numfas + 1
                ELSEIF b$(i) = "r" AND tray$(i) = "r" THEN
                        acc$(i) = "H"
                        numhits = numhits + 1
                ELSEIF b$(i) = "n" AND tray$(i) = "l" THEN
                        acc$(i) = "F"
                        numfas = numfas + 1
                ELSEIF b$(i) = "n" AND tray$(i) = "r" THEN
                        acc$(i) = "M"
                        nummisses = nummisses + 1
```

```
            END IF

        NEXT i
        hitrate = numhits / 12  '*** 12 chances to get a "Hit"
        farate = numfas / 12    '*** 12 chances for a "FA"
        PRINT
        PRINT "Hit Rate = "; hitrate
        PRINT "False Alarm Rate = "; farate

        PRINT "hit any key to continue..."
        a$ = ""
125     a$ = INKEY$: IF a$ = "" THEN 125

RETURN

'****************************************************************************
'


'********** Subroutine to save data ****************************

save:
        CLS
        LOCATE 12, 15
75      PRINT "Enter valid DOS filename and extension"
        LOCATE 13, 15
        PRINT "Include drive and path data in the following"
        LOCATE 14, 15
        PRINT "format:  a:\filename.DAT  >>> ";
        INPUT filename$
        y$ = ""
        INPUT "Enter Y to confirm >>> ", y$
        IF y$ <> "y" AND y$ <> "Y" THEN GOTO 75

        OPEN filename$ FOR OUTPUT AS #1
        PRINT #1, subject$
        PRINT #1, exposure
        PRINT #1, traynum
        PRINT #1, hitrate
        PRINT #1, farate
        PRINT #1, rtmean
        PRINT #1, rtsd

        i% = 0
        FOR i% = 1 TO nt
           PRINT #1, b$(i%)
        NEXT i%

        i% = 0
        FOR i% = 1 TO nt
```

```
        PRINT #1, tray$(i%)
     NEXT i%

     i% = 0
     FOR i% = 1 TO nt
        PRINT #1, acc$(i%)
     NEXT i%

     i% = 0
     FOR i% = 1 TO nt
        PRINT #1, rt(i%)
     NEXT i%


     CLOSE #1
     CLS : PRINT "File saved"
RETURN 99
'******************** end subroutine for saving setup *********************
'
'
'*********** Subroutine to get old setup file ******************************

getdata:
     CLS
     LOCATE 12, 2
     INPUT "Enter a:\filename.DAT of file to get >>> ", filename$
     OPEN filename$ FOR INPUT AS #1

     INPUT #1, subject$
     INPUT #1, exposure
     INPUT #1, traynum
     INPUT #1, hitrate
     INPUT #1, farate
     INPUT #1, rtmean
     INPUT #1, rtsd

     i% = 0
     FOR i% = 1 TO 24
        INPUT #1, b$(i%)
        'PRINT "b$ = "; b$(i%)
     NEXT i%

     i% = 0
     FOR i% = 1 TO 24
         INPUT #1, tray$(i%)
        'PRINT tray$(i%)
     NEXT i%

     i% = 0
     FOR i% = 1 TO 24
        INPUT #1, acc$(i%)
        'PRINT acc$(i%)
```

```
NEXT i%

i% = 0
FOR i% = 1 TO 24
   INPUT #1, rt(i%)
   'PRINT rt(i%)
NEXT i%

i = 0

FOR i = 1 TO 24
        IF tray$(i) = "l" THEN
                friendRTsum = friendRTsum + rt(i)
                friendRTsqr = friendRTsqr + (rt(i) * rt(i))
        ELSEIF tray$(i) = "r" THEN
                foeRTsum = foeRTsum + rt(i)
                foeRTsqr = foeRTsqr + (rt(i) * rt(i))
        END IF
NEXT i

friendRTmean = friendRTsum / 12
foeRTmean = foeRTsum / 12

friendRTsumsqr = friendRTsum * friendRTsum
friendRTvariance = (1 / (12 - 1)) * (friendRTsqr - ((friendRTsumsqr) /
12))
friendRTsd = SQR(friendRTvariance)

foeRTsumsqr = foeRTsum * foeRTsum
foeRTvariance = (1 / (12 - 1)) * (foeRTsqr - ((foeRTsumsqr) / 12))
foeRTsd = SQR(foeRTvariance)

'PRINT
'cls
PRINT "Subject initials = "; subject$
PRINT "Exposure time = "; exposure
PRINT "Tray number = "; traynum
PRINT "Hit rate = "; hitrate
PRINT "False alarm rate = "; farate
PRINT "Mean RT for trial block = "; rtmean
PRINT "SD RT for trial block = "; rtsd
PRINT "Mean friend RT = "; friendRTmean, "friend RT sd = "; friendRTsd
PRINT "Mean foe RT    = "; foeRTmean, "foe RT sd    = "; foeRTsd
PRINT
PRINT

i = 0: PRINT "Subject's responses: ";
FOR i = 1 TO 24
        PRINT b$(i);
NEXT i
PRINT
i = 0: PRINT "Correct responses:   ";
```

```
        FOR i = 1 TO 24
                PRINT tray$(i);
        NEXT i
         PRINT

        i = 0: PRINT "Outcome:             ";
        FOR i = 1 TO 24
                PRINT acc$(i);
        NEXT i

        PRINT
        PRINT
        PRINT "Hit any key to clear screen and end"
        a$ = ""
105     a$ = INKEY$: IF a$ = "" THEN 105
        CLS : END
RETURN

'***************************************************************************
'
'************ Error Handling Subroutine ************************************
'handler:
        SELECT CASE ERR
                CASE 64 ' Bad file name to OPEN
                'Needs to be able to tell where this error came from
                        t$ = ""
                        PRINT "You chose a bad filename..."
                        PRINT "Enter T to try again -"
                        PRINT "else any key for main menu";
                        INPUT t$
                        IF t$ = "t" OR t$ = "T" THEN
                                RESUME 're-enter filename
                        ELSE
                                RESUME 'main menu
                        END IF


                CASE 61 ' Disk full
                        t$ = ""
                        PRINT "Disk is full..."
                        PRINT "Insert new disk and enter T to try again -"
                        PRINT "else any key for main menu";
                        INPUT t$
                        IF t$ = "t" OR t$ = "T" THEN RESUME ELSE RESUME  'main
menu


                CASE 72 ' Disk error
                        t$ = ""
                        PRINT "Disk error (wrong format, bad disk, etc.)..."
                        PRINT "Insert new disk and enter T to try again -"
                        PRINT "else any key for main menu";
```

```
                INPUT t$
                IF t$ = "t" OR t$ = "T" THEN RESUME ELSE RESUME 'main menu


        CASE 71 ' Drive not ready
                t$ = ""
                PRINT "Disk drive not ready..."
                PRINT "Make sure disk is present and"
                PRINT "drive door is closed."
                PRINT
                PRINT "Enter T to try again -"
                PRINT "else any key for main menu";
                INPUT t$
                IF t$ = "t" OR t$ = "T" THEN RESUME ELSE RESUME 'main menu


        CASE 53, 76 ' File or path not Found
                t$ = ""
                PRINT "File or Path not found..."
                PRINT
                PRINT "Enter T to try again -"
                PRINT "else any key for main menu";
                INPUT t$
                IF t$ = "t" OR t$ = "T" THEN RESUME ELSE RESUME 'main menu

'               CASE ELSE:
'    2                   ON ERROR GOTO 0
    END SELECT
'RETURN
```